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Exploring the Effect of Bilingualism on Working Memory Performance:

A Case Study of Third Year EFL Students at Yahia Fares University, Medea

A Dissertation Submitted in Partial Fulfillment of the Requirements for Master Degree in English (Linguistics)

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DECLARATION

We herby declare that this dissertation entitled" Exploring the Effect of Bilingualism on Working Memory Performance: A Case Study of Third Year EFL Students at Yahia Fares University, Medea", has been undertaken by us for the requirements for Master Degree in English Applied linguistics under the supervision of Ms. Hiba Zaidi. We also declare the materials of this research are the pure outcome of our investigation and do not incorporate any substances previously written or published by other researchers except those indicated in quotations, citation or in the references list.

We are duly informed that any person practicing plagiarism will be subject to disciplinary sanctions issued by the university authorities under the rules and regulations in force.

DEDICATION

We would like to expand a special dedication to all the individuals who collaborated on this study with us. As we shared our knowledge, skills, and ideas, we are grateful for their unwavering commitment that made this study possible.

To our families, friends, and loved ones, we express our sincere appreciation for their support and encouragement throughout our academic journey. Without their love and understanding, we would not have been able to achieve our goals or reach new heights in both academic and professional careers.

This study would not have been possible without the collaboration and hard work of all three of us, and we would like to express our gratitude to one another for our dedication and commitment to this project.

Lastly, we dedicate this research to all the people who seek to expand their knowledge about the present study.

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Thank you all.

ABSTRACT

The relationship between bilingualism and working memory sparked a considerable interest in recent years. Working memory is a cognitive process that refers to the temporary storage and manipulation of information. On the flip side, bilingualism is viewed from a cognitive point of view as a personal capacity of acquiring two language systems. This exploratory case study aims at investigating the effects of bilingualism on working memory performance by comparing bilingual and monolingual third year students' level of decoding a set of English speech samples at Medea University. The study has harnessed a quantitative -based method, using the Language and Social background questionnaire (LSBQ) along with the EF SET English proficiency test, to categorize the sample which consisted of 20 third year students. The sample encompasses 10 monolinguals, 5 high proficient and 5 low proficient bilinguals. WM performance was assessed through 2back task and Corsi task to assess both verbal and visuospatial working memory capacity via testing the participants' identification and discrimination abilities. The data obtained were analyzed using the Statistical Package for the Social Sciences (SPSS) in addition to ANOVA1.The findings demonstrated that bilingualism has a remarkably positive effect on the verbal working memory performance, yet a subtle effect could be captured on the visuospatial WM. Thus, the bilingual-bound effect has been observed among bilingual students; however, second language proficiency level had no impact on the bilinguals' performance suggesting that the bilingual experience as a whole is what enhances the WM performance.

Key Terms: Bilingualism; Working Memory; Second Language Proficiency, discrimination, identification.

الملخص

أثارت علاقة ازدواجية اللغة والذاكرة العاملة اهتماما كبيرا في السنوات الأخيرة. تعتبر الذاكرة العاملة عملية معرفية تشير إلى التخزين المؤقت للمعلومات والتلاعب بها. على الجانب الآخر، يُنظر إلى ازدواجية اللغة من منظور معرفي على انها القدرة الشخصية على اكتساب نظامين لغويين. تهدف دراسة الحالة الاستكشافية هذه إلى التحقيق في تأثير ازدواجية اللغة على أداء الذاكرة العاملة من خلال مقارنة بين الطلاب لثنائيي اللغة واللغة الواحدة في السنة الثالثة بجامعة المدية. اتبعت هذه الدراسة نهجا كميًا حيث تم استخدام استبيان الخلفية اللغوية جنبًا إلى جنب مع اختبار إتقان اللغة الإنجليزية من اجل تصنيف العينة التي تتكون من 20 طالبًا جامعيًا. تشمل العينة 10 طلاب أحادي اللغة، 5 طلاب ذوي لغة عالية الكفاءة و5 اخرون ذوي لغة منخفضة الكفاءة. تم تقييم أداء الذاكرة العملية عن طريق اختبارين لتقييم قدرة الذاكرة العملية اللفظية والبصرية من خلال اختبار قدرات المشاركين على التعرف والتمييز. تم تحليل البيانات التي تم الحصول عليها باستخدام الحزمة الإحصائية للعلوم الاجتماعية بالإضافة الى انوفا1. أظهرت النتائج تأثير ايجابي لازدواجية اللغة على الذاكرة العملية اللفظية ولكنها اظهرت ميزة طفيفة في الذاكرة العملية البصرية المكانية. وبالتالي، لوحظ امتياز ازدواجية اللغة بين الطلاب ثنائيو اللغة. لم يكن لمستوى الكفاءة اللغوية الثانية أي تأثير على أداء مزدوجي اللغة مما يشير إلى أن تجربة ازدواجية اللغة ككل هي التي تعزز أداء الذاكرة العاملة.

الكلمات المفتاحية: ازدواجية اللغة ;الذاكرة العاملة ;الكفاءة اللغوية الثانية ;التمييز ;التعرف.

GLOSSARY

Terms	**Definition**
Bilingualism	The ability to speak two languages.
Cognitive control	Cognitive control" is a construct from contemporary cognitive neuroscience that refers to processes that allow information processing and behavior to vary adaptively from moment to moment depending on current goals, rather than remaining rigid and inflexible.
Cognitive load	The relative demand imposed by a particular task, in terms of mental resources required. Also called mental load; mental workload.
Executive control	the ability to carry out goal-directed behavior using complex mental processes and cognitive abilities (such as working memory and impulse inhibition)
Inhibition	An inner impediment to free activity, expression, or functioning: such as**:** a mental process imposing restraint upon behavior or another mental process (such as a desire).
Multilingualism	Using or able to use several languages especially with equal fluency.
Neuroplasticity	The ability of the nervous system to change its activity in response to intrinsic or extrinsic stimuli by reorganizing its structure, functions, or connections.
Short-term memory	Memory that involves recall of information for a relatively short time (such as a few seconds).
Working memory	Memory that involves storing, focusing attention on and manipulating information for a relatively short period of time (such as a few seconds).

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LIST OF ABBREVIATIONS

WM:	Working memory.
EC:	Executive control.
EF:	Executive functions
HPB;	High proficient bilingual
LPB	Low proficient bilingual
LSBQ:	Language and Social Background Questionnaire
EF SET:	EF Standard English Test

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General Introduction

GENERAL INTRODUCTION

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General Introduction

1. Background and Motivation for the Study

Bilingualism, being a multifaceted phenomenon, has made it a challenge to establish a universally agreed-upon definition. Traditionally speaking, bilingualism has been viewed as the individual's capacity to speak two languages, thereby, indicating the existence and usage of two distinct linguistic systems. Hence, it is considered as a personal and subjective characteristic. This can be referred to as cognitive bilingualism. From another perspective, it can be considered as "a societal construct to describe the interactions between social groups and societal institutions; it is concerned with between-group interactions in which the two languages serve as a symbol over which interaction occurs". (Hakuta, Ferdman&Diaz, 1987, p.285). Simply put, bilingualism is liable to be identified within two main areas: individual bilingualism and societal bilingualism. Our main focus in this research is the individual-cognitive bilingualism.

Moreover, Bilingualism is an interdisciplinary phenomenon that is intertwined with other fields of research that extend beyond the realm of linguistic studies. One of its tightly related domains is cognition. Researchers have long been intrigued to explore the connection between bilingualism and cognitive control. Early studies predominantly explored the potential negative effects of bilingualism on cognitive abilities, suggesting that speaking multiple languages could lead to confusion or cognitive disadvantages. However, subsequent research has made it evident that these findings were influenced by methodological limitations and biases. More recent investigations have provided compelling evidence of the cognitive advantages associated with bilingualism, particularly in terms of cognitive control.

The context in which bilingualism affects cognitive control is manifested within the functional neuroplasticity of the brain, where experiences modulate brain structure and enable cognitive flexibility. Given that being bilingual is a lifelong experience, it paves the way to hypothesize that it bears a necessary repercussion on cognition. Indeed, research has shown that bilingualism has a positive influence on executive functions. According to Bialystok (2012), bilingualism has been associated with enhanced executive functions, which are cognitive processes involved with attention, inhibition, and working memory. In this regard, Kroll & Stewart (1994) offered a plausible explanation for these noticeable effects prior to bilingualism. They suggested that bilingual individuals experiencing enhanced executive

functioning are an outcome of their need to constantly monitor both languages, manage lexical interference, and inhibit conflicting information. From this line of reasoning, the notion of the improvement of inhibitory control has stemmed. Nevertheless, it is important to recognize that the body of research regarding this topic is inconsistent and the particular impact of bilingualism on executive function is not always apparent. Thus, further investigation is necessary to take place in order to unveil the true nature and extent of any cognitive advantages associated with bilingualism.

2. Statement of the Problem

The relationship between bilingualism and working memory is one of a complex nature that cannot be encapsulated easily. Working memory is a cognitive system that is responsible for temporarily maintaining and altering information in the mind during challenging tasks. Hence; it is difficult to empirically measure its capacity. To be more specific, given that the WM operates in a dynamic and multidimensional manner, this renders the task of establishing an exact measure of it very difficult as it entails not only the storing of information, but also its active manipulation and processing.

Working memory capacity is often measured through tests that demand participants to retain and handle an array of information over a short period of time. These tasks frequently require recalling and updating information, suppressing irrelevant data, and shifting between cognitive processes. Still, accurately assessing the precise capacity of working memory remains elusive due to the complexities involved in isolating and quantifying its underlying mechanisms. Consequently, it has become challenging for researchers to measure its capacity under the effect of external variables such that of bilingualism.

Based on the body of literature related to the issue of the potential effect of bilingualism on WM; research findings are not consistent. While some studies observed a positive influence of bilingualism on working memory, the major part of other experimental studies reported no significant differences between bilinguals and monolinguals in terms of their working memory performance. In recent studies, these null findings were attributed mainly to methodological inconsistencies, particularly in terms of the sampling procedures. The population investigated across the studies was not as homogenous as it is entailed because the host of the variables, including the proficiency level, social and educational background, and age of second language acquirers, peculiar to address the effect of bilingualism on WM were mostly discarded. Thus, through the current research, we attempted to opt for a rather

comprehensive investigation of the effect of bilingualism on WM performance across third year bilingual and monolingual students at Yahia Fares University of Medea by minimizing the methodological hurdles (ensuring a homogeneous study sample) so as to unveil the possible relationship between bilingualism and working memory. Accordingly, a number of research sub-questions are raised as follows.

2. Research Questions

In this study, we aim at exploring the possible effects of bilingualism on working memory performance by addressing the following main inquiry:

Main question:

- Does bilingualism influence working memory performance?

To add more nuance to the inquiry, two further sub questions were developed:

1. Does students' level of language proficiency affect the identification ability of their working memory?

2. Does students' level of language proficiency impact their discrimination processing of working memory?

In light of the aforementioned questions, it is possible to lay the following hypotheses.

4. Research Hypotheses

Throughout this research endeavor, we will seek to investigate the following hypotheses:

1. Bilingualism positively affects working memory capacity.

2. Students' particular level of language proficiency will impact the identification ability of their working memory.

3. Students' particular level of language proficiency will influence the discrimination ability of their working memory.

5. Significance of the Study

The significance of the current research is to find a way for setting an association holding between bilingualism and working memory. By unveiling this relationship, researchers can uncover the underlying mechanisms and potential advantages associated with

bilingualism. In this study, our objectives extend beyond examining the disparities between monolingual and bilingual individuals to rather investigate the potential effect of second language proficiency on working memory. To achieve this, we will assess both the identification and discrimination abilities that come into play during engagement in working memory tasks. By examining these aspects, we can gain a comprehensive understanding of how second language proficiency impacts the cognitive processes involved in working memory, including the ability to recognize and differentiate stimuli within a given working memory context.

Moreover, this study seeks to investigate two fundamental functions of working memory, thereby providing a comprehensive analysis. The use of the N-back task will offer insights into individuals' verbal working memory capacity, specifically their ability to retain and manipulate verbal information. On the other hand, the Corsi task will assess participants' visuospatial working memory capacity, examining their capability to retain and manipulate spatial information. Unlike previous studies that may focus on only one aspect of working memory, this study seeks to shed light on both the verbal and visuospatial components of working memory, allowing for a more exhaustive and holistic understanding of its functional aspects.

By doing so, this study seeks to strengthen the existing body of knowledge by offering empirical evidence and supporting the findings through concrete data. By means of the employed research methods and techniques that include the N-Back task and the Corsi task, we aspire to enhance the comprehensiveness and reliability of the existing knowledge prior to the WM based on pinpointing the nature of the relationship between bilingualism and working memory.

6. Objectives of the Study

Given that the impact of bilingualism on cognition and executive functions remains largely unexplored, particularly regarding its influence on working memory, this research aims at investigating the effect of bilingualism on the working memory performance of third year monolingual and bilingual students at Yahia Fares University. Our aim is to find empirical-based evidence that supports or refutes the suggested hypotheses through a systematic investigation of the potential effect of the students' particular level of language proficiency (be it high or low) on their working memory performance. By doing so, we hope

to contribute to the existing knowledge in the field and gain a deeper understanding of the relationship between the two constructs.

7. Structure of the Thesis

This research adheres to the conventional structure of the traditional simple model, comprising an introductory section, four main chapters, and a concluding section. The first introductory section is a general introduction to the current thesis in which we present a short background covering the research topic alongside stating the problem and significance of the research and its aims. It also presented the research questions and the hypotheses formulated to answer them. The section ends with showcasing the skeleton of the thesis.

The first chapter of the thesis encompasses a comprehensive literature review. This chapter delves into the various approaches and studies conducted in the field of bilingualism and working memory, aiming to establish a solid understanding of the research area. Key concepts, such as bilingualism, working memory, and language proficiency, are clearly defined and elaborated upon. Additionally, the chapter delves into the underlying cognitive processes that contribute to working memory performance, specifically focusing on identification and discrimination processes. Moreover, the role of language proficiency and its potential impact on cognitive development is thoroughly explored. By addressing these aspects, the first chapter provides a robust framework for the subsequent analysis and discussion presented throughout the thesis.

In the second chapter, we dive into the research methodology employed in this study. Our focus is on introducing the approach taken to gather and analyze the data. Firstly, we provide a detailed explanation of the target population and the procedures we followed to select the participants for this research. We then elaborate on the various data collection instruments that were utilized to gather the necessary information for our investigation. Moving forward, we engage in a comprehensive discussion of the quantitative procedures employed to analyze the data that we gathered. This chapter serves to provide a clear and transparent account of the methodology implemented, ensuring the rigor and validity of our research findings.

In the third chapter, we exclusively analyzed the collected data and presented it in a graphic representation. This chapter specifically focused on the results obtained from the two data collection instruments, while including the preliminary test results that were used solely to establish the study's credibility and ensure no external influence on the final outcomes. Significantly, we conducted statistical analysis on both working memory tests using the Statistical Package for the Social Sciences (SPSS) and reported the findings of the dependent variables.

Chapter four focuses on the analysis and interpretation of the quantitative data gathered by the researcher. It provides a comprehensive discussion of the research findings, addressing both the main research question and the sub-questions in detail. Additionally, we assessed the compatibility between the presented hypotheses and the outcomes of this study. Finally, the limitations of the research were presented alongside the study implications and suggestions for further investigation.

Chapter One

Literature Review

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Chapter One: Literature Review

Introduction

Bilingualism has long been a topic of interest in the field of cognitive development, particularly with regards to its impact on working memory. According to Lambert (1996), Bilingualism refers to the use of two or more languages. To Conway (2007), working memory involves the temporary storage of information while manipulating its items. Upon initial examination, there seems to be no apparent link between the two constructs. However; many prior theories have laid the ground to investigate this possible relationship. The threshold hypothesis by Cummins entails that proficiency in a second language brings about a load of cognitive gains which reinforce executive functions such as working memory. Connectionist views also entail further explanation in which the joint activation of two languages exhibits positive impact on the executive functions namely inhibitory control, thus; it is assumed that it offers similar advantages to the working memory. In this chapter we pin down the definitions adopted for this research; alongside with the theoretical foundation that supports the positive effects of bilingualism on working memory. Moreover, the chapter depicts an overview of the followed WM Baddeley's model alongside identification and discrimination abilities of working memory that are measured through the recognition of targeted stimuli and reaction time respectively. Finally, we present a review for the controversial Bilingual Executive Advantage Hypothesis (BEA) in addition to a variety of previous studies that are relevant to the research topic.

1.1 Bilingualism

Bilingualism is a widespread phenomenon across the world that is described with various definitions. This has made it challenging to pinpoint a holistic definition that is agreed upon by linguists. Traditionally speaking, bilingualism has been viewed as an individual capacity to speak two languages. That is, individuals who possess or use two linguistic systems. Moreover, this phenomenon has expanding dimensions varying from socio-cultural to educational aspects and linguistic to cognitive dimensions. In this research, we focus mainly on the cognitive aspects of bilingualism and its relation to executive functions.

1.1.1 Definitions of Bilingualism

Bilingualism is the ability to speak and understand two languages fluently. It is a complex phenomenon that has been studied extensively in recent years. Scholars have offered a variety of definitions to bilingualism, but most agree that it involves the active use of two languages in a person's daily life.

Macnamara (1967) noted that " *a bilingual is anyone who possesses a minimal competence in only one of the four language skills, listening comprehension, speaking, reading and writing, in a language other than his mother tongue".* As cited in (Hamers &Blanc, 1989, p.6). Parallelly, Lambert (1996), pointed out that bilingualism is "*the ability to use two languages with an equal level of fluency*. This definition highlights the importance of exploring bilingualism in light of proficiency in both languages, rather than just restricting it to the ability to understand or speak them. In this regard, Cummins (2008) stated that: "*Bilingualism is the cognitive and linguistic ability to understand and produce language in two different systems of grammar and vocabulary, with equal or varying degrees of proficiency*." (p. 4). This triggers the cognitive and linguistic intricacy of bilingualism with a clear focus on the importance of proficiency regardless of its varying degrees in the matter.

In terms of the social-based dimension of bilingualism, it is regarded *as "the use of two or more languages or dialects, either by an individual speaker or by a community of speakers*." (Grosjean, 2010, p. 1). It is also captured by Maurais (2003) as: *«the mastery of two or more languages or language varieties by an individual or a group, which is acquired and used in a specific social context*."(p.3). He emphasizes the social and situational aspects of bilingualism besides the linguistic abilities of the individual.

1.1.2 Types of Bilingualism

There are different types of bilingualism, each with its unique characteristics. The different typologies are based on the age of language acquisition (early or late bilinguals) and levels of proficiency (dominant or balanced) and manners of acquisition (learned or acquired). The most commonly recognized types of bilingualism will be presented as follows.

According to Beardsmore (1986), there are two types of bilingualism. Early bilingualism refers to the acquisition of more than one language in the preadolescent phase of life. Late bilingualism referred to the acquisition of one language before the other language after the age of 8 years old. Concerning the early bilingualism, it embraces two types**.** First, simultaneous bilingualism refers to when a child learns two languages at the same time from

birth or very early age. The child is able to switch between the two languages with ease, and proficiency in both languages develops simultaneously. The second type is known as sequential bilingualism in which it happens when a child learns a second language after having already acquired a first language. The child may have some difficulty switching between the two yet proficiency in both languages develops over time.

Furthermore, Beardsmore (1986) proposed that late bilingualism refers to the acquisition of a second language after the age of 8 years old. It can be categorized into two distinct types: additive bilingualism and subtractive bilingualism. Additive bilingualism refers to the process of acquiring proficiency in an additional language while maintaining proficiency in the first language. This type of bilingualism is especially characterized by a positive effect on the individual's cognitive, social, and linguistic development. On the other hand, subtractive bilingualism occurs when a person loses proficiency in their first language as they acquire a second language. This type is often observed in immigrant children who do not receive support in their first language, leading to a decline in fluency over time.

While the classification of the types mentioned above seems to be based on the age and period of acquisition of the second language; another important categorization is expressed through the ratio of the fluency and proficiency of the two languages; as suggested by Peal and Lambert (1962), which includes further two distinctions. Balanced bilingualism could be seen in a person who is more or less equally proficient in both first and second language. Dominant bilingual however, is observed when a person being more proficient and competent in one of the two languages and in most cases native-like.

Our study is geared towards exploring the phenomenon of bilingualism in balanced late bilinguals, more specifically the additive bilinguals as it is the largely captured type among third year students at Medea University.

Upon explaining the various types' bilingualism embraces, it is also necessary to touch upon the nature of second language proficiency and its relationship with cognitive development; Particularly; its impact on working memory.

1.1.3 Language Proficiency:

A bundle of studies have captured a mingled relationship between language proficiency and cognitive development. While there is a variety of definitions prior to determine the compository elements of language proficiency, Cummins and Davison (2007)

have thoroughly deciphered the concept as: *"Language proficiency is a complex construct that involves not only the mastery of linguistic form and meaning, but also the ability to use language appropriately in different contexts, to understand and interpret a wide range of discourse types, and to interact effectively with others"* (p.17). Furthermore, Cummins (1979) posited an explicit distinction between two different types of proficiency: Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP). While BICS refers to the social language skills that are necessary for everyday communication, such as conversational fluency, CALP "*relates to the dimension of language proficiency which is strongly related to overall cognitive and academic skills*." (Cummins, 1979, p.2). That is; it is linked to the academic language skills that are necessary for success in academic settings, such as reading, writing, and critical thinking. Cummins (1976) noted that after reaching certain threshold in academic proficiency (CALP); individuals may entertain certain level of cognitive reinforcement.

In the same line of thought, Hakuta et al (1987) and Duncan and De Avila (1979) maintained that proficient bilinguals are ranked higher than any other proficiency group on all cognitive measures. According to the findings of their studies, partial bilinguals, limited bilinguals, and monolinguals revealed no significant differences. Therefore, there has been the claim that language proficiency may have a positive influence on cognitive development.
This lays support for Cummins's Threshold Hypothesis which reckons the principle that after a certain threshold of proficiency in two languages, bilingualism leads to positive cognitive gains.

1.1.3.1 The Threshold Hypothesis:

The Threshold Hypothesis is one of the prominent theoretical frameworks in the field of bilingualism and cognition. The hypothesis was first introduced by Cummins (1979) taking on the position that when students attain a certain threshold of proficiency; it leads to growth in cognition and academic success. To wit, Cummins (1976) stated:

" Based on the fact that the development of age-appropriate proficiency in two languages appeared to be associated with cognitive advantages, whereas the attainment of only relatively low levels of bilingual proficiency was associated with cognitive disadvantages, it was hypothesized that there may be two threshold levels of linguistic proficiency: The first, lower, threshold must be attained by bilingual children in order to avoid cognitive disadvantages and the second, higher, threshold was necessary to allow the potentially beneficial aspects of bilingualism to influence cognitive growth" (p.3).

Alternatively put, the hypothesis suggests that highly proficient bilinguals in both L1 and L2 attain restrictively positive effects on their overall cognitive abilities. However, the hypothesis has been subject to some criticism as it lacks empirical support. In this respect, Thomas and Wayne (2002) have adversely argued that the hypothesis does not adequately account for the development of cognitive and academic skills in the second language. They suggest that a more comprehensive model is required to fully capture the relationship between language proficiency and academic achievement. Krashen (1982) has also noted that the concept of a threshold level of language proficiency oversimplifies the relationship between language proficiency and academic achievement. He suggests that the relationship is more complex and that language proficiency may interact with other factors. Additionally, Takakuwa (2005) criticized the hypothesis for defining thresholds in a relative sense and setting up arbitrary within-group thresholds, resulting in countless threshold levels and rendering the hypothesis meaningless. Besides, "*the research has also over-relied on statistical significance and explored relationships of association rather than causality, limiting generalizability and replicability"*. (Ardasheva, Tretter&Kinny, 2012, p. 775).

Despite the above mentioned critiques, this study seeks to pursue the effects of L2 proficiency level on nonverbal cognitive tasks harnessing the main principles of the Threshold Hypothesis which seems adequate to explore the possible influence of language proficiency on executive tasks, namely the working memory performance.

1.2 Executive Functions

According to Bialystok (2012), "*Executive control is the set of cognitive skills based on limited cognitive resources for such functions as inhibition, switching attention, and working memory" (as cited in Diamond, 2013).* It is alternatively labeled as cognitive control or executive control. Executive functions (EF) are deemed as necessary mental processes involved in concentration and attention incorporated within the different tasks that an individual performs. Letho et al. (2003) identified three core classes of the executive functions: inhibition that covers the inhibitory control and self-control, commonly known as behavioral inhibition, as well as inference control that covers cognitive inhibition and selective inhibition, working memory, and cognitive flexibility. Based on these components of EF, higher-order EFs are generated by naming problem-solving, reasoning, and planning (Collins, Kroechlin and Lunt et al. (as cited in Dimond, 2013).

1.2.1 Selective Attention

In an attempt to capture the possible link between bilingualism and attention, Bialystok (2017) conducted an experimental study on bilingual adaptation to the minds in order to unveil its potential enhancement effect on the cognitive performance observed in infants, children, and young adults raised in different environments. The study yielded remarkable findings regarding the significant trace prior to mark the way bilingualism and cognitive functions are related. She proved that this link can be highlighted even in infants (about 7 months old) raised in environments where they hear more than a single language. She noted that these infants maintain attention to the different phonetic distinctions as well as using their visual cues (visual attention) to detect when a speaker has switched the language used even in the absence of the auditory information. In another study about bilingualism, age, and cognitive control carried by Bialystok, Craik, Klien, and Viswanathan (2014), showed that the ability to switch between two languages and suppress the unnecessary information tends to improve with bilingual experience which may lead to improvements when it comes to cognitive abilities in performance in various tasks such as, Simon effect as it has a direct link to selective attention. To further support this claim, Chung-Fat-Yim, Calvo, and Grundy (2022) found that bilingualism affects attention. The effect is rather grounded on selective attention, which is considered as a bilingual enhancement.

1.2.2 Inhibitory Control

It has widely been claimed that bilinguals are more likely to activate both language systems when intending to speak. This stems from some psycholinguistic-based studies (cross-language priming, in which a word in one language facilitates retrieval of a semantically related word in the other language) and lexical decision tasks (in which participants decide whether a string of letters is a legal word in one of the languages) that show the influence of the currently unused language for both comprehension and production of speech (Bialystok, 2012, p.3). Such studies have indicated what is known as the joint activation of language which postulates that when a speaker needs linguistic access in a situation, he/she is provided with both systems of L1 and L2 to decide on which system to adapt to according to the instant context. This selection problem is believed to be solved through the inhibitory control model which is a model that embodies the principle that there are multiple levels of control. *" In this model, a language task schema, modulated by a higher level of control, reactively inhibits potential competitors for production at the lemma level by*

virtue of their language tags "(Green, 1998, p. 71).That is to say, potential outputs of the lexico-semantic systems that compete when activated are inhibited depending on the goal of the speaker. Consequently; the inhibitory control is enhanced by means of the bilingual experience in which the constant use and switch of languages exercises the mental cognitive process.

1.2.3 Working Memory

The conception of the Working Memory was caught by Baddeley (1974) " *as a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning* "(as cited in Pérez, 2012). Parallelly, Conway (2007) stated that: "Working memory (WM) generally refers to our ability to 'mentally maintain information in an active and readily accessible state while concurrently and selectively processing new information."(As cited in Wen et al., 2022)

1.2.3.1Baddeley's Working Memory Model:

Among the different prominent working memory models, we opted for the Baddeley and Hitch working memory model (1974), for it brings one of the most influential working memory measures. In addition to what it possesses of logical linguistic rationality as held by Mills (2000) (as cited in Filgueiras, 2015), this model was put forward under a theoretical foundation called the "Information Processing Theory" that emerged as an approach to language adversary to the overall claims of behaviorism. The model hinges upon four components of the working memory, namely:

1) The phonological loop: according to Demir& Bora (2021) it is a system in charge of handling verbal and auditory input; it manages the phonological information being received and rehearses the verbal input (p.4)

2) The visuospatial sketchpad: A slave system that functions for the processing of visual and spatial input (Morris & Greenberg, 2005)

3) The episodic buffer: according to Baddeley; the episodic buffer is responsible for managing both the visual and speech-based input .He identified the episodic buffer as a connector between as he puts it "…*visual and verbal information together with their semantic association*. " (Baddeley, 2019, p.289).

4) The central executive: it is the most important component on which the WM model is built. Baddeley and Hitch (1974) considered the central executive to be the workspace that is flexible to adjust to the different tasks yet limited in capacity, which makes it a complex system that handles both of the depositories along with the computational processing of the given input. As for Baddeley, the central executive is responsible for the control of executive processes, including actions; the direction of attention to relevant information, as well as the suppression of irrelevant information and undesired actions; the supervision of information integration; the coordination of multiple cognitive processes to be executed in parallel; and the coordination of the sub-systems of WM. (as cited in Pezzulo, 2007).

1.2.3.2 Measure of Working Memory

One of the most popular measures in the field of cognitive psychology is the identification and discrimination processes alongside reaction time. These two dependent variables could reveal necessary information about one's cognitive abilities. Hence, they can supply us with significant findings on the inscrutable capacity of working memory. In fact, most studies have adopted a similar approach to examine the working memory performance based on participants' data on the reaction time and their perceptual abilities of identification and discrimination

1.2.3.2.1 Identification and Discrimination

Identification and discrimination are two perceptual processes that are strongly related to working memory. Discrimination refers to "*the ability to distinguish between stimuli or objects that differ quantitatively or qualitatively from one another"*. (APA, 2015, p.320).Identification refers to "*the process of recognizing or categorizing a stimulus based on its features or attributes* (Eysenck & Keane, 2015), that is; the ability to recognize a stimulus and identify it to a certain category. This correlates with working memory, in which external or internal stimuli should be identified first in order to be stored or inhibited. Likewise, the Discrimination ability is equally related to WM in which it reveals the rate of reaction that has been taken by individuals in order to discriminate and distinguish between similar stimuli.

Many studies have captured a positive relation between the construct of identification and discrimination with working memory. One study conducted by Kane, Bleckley, Conway & Engle (2001) demonstrated a positive link between identification and working memory through a pro-saccade task in which a visual cue appeared in the same location as a subsequent to-be-identified target letter.(Kane et al, 2001,p. 169).

1.2.3.2.2 Time Reaction

According to the American Psychological Association, reaction time (RT) is defined as "*the time that elapses between the onset or presentation of a stimulus and the occurrence of a specific response to that stimulus" (*APA, 2015, p.883). That is the time interval between the onset of a stimulus and the initiation of a response. It is commonly used to measure the speed and efficiency of information processing in the cognitive system.

Reaction time is exclusively related to the discrimination ability as it signals individual differences in the time consumed to discriminate between similar stimuli. Hence, reaction time is a tool adopted by cognitive psychologists to determine the efficient capacity of the discrimination process.

1.2.3.2.3 Worst Performance Rule:

*The worst performance rule (WPR) is a phenomenon in which "individuals' slowest responses in a task are more predictive of their intelligence than their fastest or average responses."(*Larson& Alderton, 1990) as cited in (Schubert, 2019, p.1). That is to say, individuals ' intelligence and cognitive abilities, in general, are not determined by faster response time as it was formerly believed, however, the slower response times (RTs) have much to reveal about a person's cognitive processing. Theoretical interpretations of this phenomenon are mainly based on the view that lapses of attention and/or working memory result in longer RTs and those individuals of higher intelligence have usually better capacities of attention control, preventing such lapses (Jensen, 1992; Larson & Alderton, 1990; Engle, 2002).as cited in (Schubert, 2019,p.415).

As a matter of fact, an influential model has been proposed to account for the worst performance rule that is the attention control model. This will be presented in the following sub-section.

1.2.3.2.4 The Attentional Control Model

The Attentional Control Model initiated by (Larson& Alderton, 1990) presumes that "*less intelligent individuals are more prone to occasional attentional lapses that disrupt goal maintenance in working memory.*" As cited in (Schubert, 2019, p. 89). "Low WM capacity and low reasoning ability are associated with a higher probability of temporary interruptions in information processing on a subset of trials, which could be called lapses of attention. Such lapses on some trials result in a more extended tail of the RT distribution" (Schmiedek et al, 2007, p.416). These so-called attentional lapses lead to a prolonged response time because attention needs to be redirected first to the task after the interruptions were made. Thus, the model reflects to certain degrees that slow reaction times manifest the individual differences

in managing attention. They are, therefore, more predictive of intelligence and higher-order cognitive processes such as that of working memory.

1.3 Connectionism Theory

Working memory (WM) is a cognitive ability available to store task-related contents and operate attention-related supervisory when manipulating tasks that require both information processing and memorizing. Inhibitory control (IC) refers to an attentional control that can access, delete, and restrain information and includes response control.

Based on earlier research, working memory and inhibitory control are two independent executive cognitive processes that are inextricably related. Neuro-imaging studies provide further support to this claim by indicating that both processes belong to the same brain area which is the frontal temporal lobe.

Connectionist models are" large networks of simple parallel computing elements (in this case working memory and inhibitory control) each of which carries a numerical activation value which it computes from the values of neighboring elements in the network; the network elements, or units, influence each other's values through connections that carry a numerical strength, or weight" (Smolensky, 1988)

Therefore, based on the theory of connectionism; we assume that since bilingualism affects positively inhibitory control, it might as well have some effects on working memory. We hypothesize that bilingualism sharpens the capacities of working memory as it provides a good exercise for inhibiting unnecessary information while processing task-related data.

1.3.1 The Bilingual Executive Advantages Hypothesis

The recent interest in language acquisition and its influence on the brain has resulted from many studies suggesting that speaking two or more languages offers cognitive advantages that extend beyond language skills. This led to the initiation of different hypotheses that attempt to explain the phenomenon. In this regard, Bialystok (2001) suggested that the constant use and management of two languages implies that the bilingual brain is engaging in a continuous conflict of switching and inhibiting different blocks of information in each language, which happens in order for the brain to stay focused on the language that the individual selected to use at a given moment. She further explained that this continuous process leaves traces in the brain, which in itself are the regions of the brain responsible for executive functioning and inhibitory 2.4control. Since then, many researchers were in favor of this hypothesis (e.g., Bak,

Vega-Mendoza, &Sorace, 2014, Bialystok, Poarch, Luo, & Craik, 2014; Poarch & Van Hell, 2012). They conducted more in-depth studies by investigating the validity of the bilingual advantage on different age groups, including children, young adults, and older adults. Furthermore, they explored the BEA effect by distinguishing bilinguals by measures of the age of L2 acquisition, or level of proficiency. The BEA effect gets more understood the more factors and conditions are taken into consideration while putting it to test.

While much research evidence points to the support of a bilingual advantage, the extent to which it is a reliable hypothesis is still under debate. In recent years, many studies on the other end of the spectrum failed to find results that support the idea that bilinguals have better EF abilities than their monolingual counterparts. For instance, Grundy's (2020) study suggested that the significant amount of null results is attributed to the over-simplification of the bilingual experience. i.e. factors like the particular context that involves undergoing the study or the level of proficiency in the language are things that may prevent reaching authentic results. Some other studies (e.g. Paap, Johnson &Sawi, 2016) also expressed doubt about the validity of this hypothesis. They argue that the conflicting results of numerous studies make it too inconsistent to draw any firm conclusions.

1.4 Previous Studies:

The issue of bilingualism in relation to cognition has caught the attention of a wide range of researchers in recent years. Since executive functions are cognitive processes that can be directly analyzed through observing behaviors, numerous studies have been conducted in this regard. Those studies explored the attributes marked in the EF skills of bilingual or multilingual individuals in various contexts, especially the functioning of working memory, for it is considered as the most essential component of the executive function (Kane et al., 2007). Previous studies need to be taken into consideration for they serve as a basis for the current study.

Capani (2019) has carried a study to investigate the effect of bilingualism on working memory. It was carried out on a group of 102 young adults between the ages of 18 and 29 at York University, Toronto. Among the whole population, 51 of them were bilinguals while 51 were monolinguals. The participants were engaged in two sets of memory tasks: n-back and item/associative tasks, in order to reveal the differences between the two groups in terms of WM by comparing their performances in the two tasks. In addition to the conventional

measuring method, mouse tracking was used to determine the strategies they use while completing the tasks in real-time. The results demonstrated that both bilingual and monolingual groups showed similar performance on the tasks. They did not show any significant differences in accuracy or reaction time in most of the tasks. Despite this, the mouse tracking technique revealed that bilinguals have longer initiation times and reaction times in comparison to monolinguals. Overall, the study presents a cohesive theoretical overview and a well-designed and executed experiment and analysis of the tasks. However, one limitation is the wide age range of the selected sample could create participants' variability-biased effect on the results of the research. The task results of 18 years old and 29 years old participants' performance on the same tasks under the same conditions would undoubtedly be influenced by factors other than the fact that they're bilingual. Factors like lived experience, brain development, and educational level, could undermine the reliability of the results.

Another study undertaken at Oslo Metropolitan University of Norway by Fyndanis, Cameron, Hansen, and Simonsen (2022) inspected whether multilingualism has a positive effect on verbal short-term memory and WM capacity. 82 middle-aged and older L1-Norwegian Bilingual/ multilingual academic professors and researchers were tested using the digit backward span task and digit ordering span task. The results revealed that bilingualism does grant an advantage in the verbal capacity of WM and STM. It also concluded that the more languages an individual knows, the better their verbal WM and STM capacities. The study findings also highlighted attentional control as the mechanism that is behind the advantage that bilingualism offers. The researchers offered a thorough statistical analysis that resulted in the findings being significant, still, certain limitations related to the tools of data collection used in the study can be highlighted. The participants in the experiment were chosen solely by providing a language background questionnaire where they rated their own proficiency and use of the languages they knew. This type of self-report measure is easily subjected to bias. Measures of intellectual abilities (language) are most objective and scientific when done by an external instrument like taking a standardized test or being examined by an expert in the field. Another limitation is that the study findings are far from generalizing them to a large and diverse population when the selected sample is significantly small and shares limited backgrounds.

Cockcroft, Wigdorowitz, and Liversage (2019) examined whether multilingual young adult individuals have an advantage over their monolingual peers with regards to three

components of working memory: the phonological loop, the visuospatial sketchpad, and the central executive. Taking place at the University of the Witwatersrand, Johannesburg, South Africa, the researchers conducted two experiments that consisted of various working memory tasks and involved 39 monolingual English speakers, and 39 highly proficient multilingual who spoke an African language as their first and third languages, and English as their second language. The results of this study indicated that multilingual individuals have an advantage in all three components of working memory. It further led to the suggestion that the increased cognitive demands of multilingualism, mainly the switching between languages and inhibiting irrelevant information, may lead to an enhanced working memory capacity. The findings of this study also indicated that the age of acquisition and proficiency in additional languages play a part in the multilingual advantage.

Morales, Calvo, and Bialystok (2012) surveyed Working Memory Development in Monolingual and Bilingual children through two studies. First, 56 children aged 5 years old were asked to carry a Simon-type task, which examines the manipulation of working memory demands. In the second study, 125 children who were 5 years old and 7 years old performed a visuospatial span task that put other executive functions to test such as inhibition and shifting. In both of these tasks, bilingual children outperformed monolinguals. These results landed on the supportive side of the BEA hypothesis. The researchers suggest that the increased demand on attention and cognitive control in bilinguals may lead to an enhanced working memory capacity. Additionally, the study found that age played a significant role in working memory development, as older children had better working memory than younger children.

Another study that investigated the BEA hypothesis in the field of WM is an online study that compared the working memory performance of early and late bilinguals vs. monolinguals via using 10 isomorphic verbal and visuospatial WM tasks that produced three WM composite scores: visuospatial WM, verbal WM, and n-back (Lukasik et al., 2018). They further examined whether the WM scores were related to some key features of bilingual experience (age of acquisition of L2, L2 proficiency, language-switching frequency). The experiment included 485 diverse and well-matched participants that were selected through the Amazon Mechanical Turk crowdsourcing site. Coming to The results, only the n-back test showed an advantage of late bilinguals over monolinguals and early bilinguals, while the other two scores did not show any significant difference between the performances of the two groups. Although the experiment was slightly in favor of the bilinguals, the results of this article did not show enough support for the BEA hypothesis. The researchers suggested that

these results were due to the original hypothesis not outlining the exact conditions that should be found in the bilingual experience for the BEA to emerge. While this study has its strengths, particularly in analyzing data from a large sample size of over 700 participants and using an online survey, there are some issues that we could identify. Mainly, the study did not control factors that could potentially act as confounding variables. Factors like age, education level, and socioeconomic status could distort the results of the investigation of the relationship between WM performance and bilingualism. Another limitation lies in the fact that the study was undertaken through a cross-sectional design. i.e., it analyzed data at a specific point in time. This puts a significant limit on the ability to establish a causal relationship between WM performance and bilingualism. Collecting data over an extended period of time through a longitudinal study might have been a better choice to determine causality.

All of the aforementioned studies have investigated the topic of bilingualism's relationship with working memory through a lens that focused on a statistical and analytical method. Similarly, the present study falls under the category of descriptive quantitative research, as the data is collected through a computerized WM task, and the results are presented in numerical and graphical formats. More importantly, the research papers mentioned previously emphasize some significant issues, most of which are closely related to the selected samples. This is important because the nature of the inquiry at hand requires the participants to have backgrounds that are as similar as possible in order to produce the most relevant findings. For this purpose, the current study carefully selected participants who are all third-year students in the English and Arabic departments at Yahia Fares University in Medea. These students fall within the same age range and have similar language proficiency and usage patterns in their respective language classifications. Considering such details in selecting the sample would minimize the number of external factors that could interfere with reaching applicable results. This approach grants a clearer and more accurate understanding of the extent to which bilingualism affects the WM performance. Ultimately, these findings would contribute to the general understanding of the relationship between bilingualism and executive functioning.

Conclusion:

In conclusion, this chapter studied bilingualism and its impact on working memory in the context of cognitive development. The chapter discussed related hypotheses such as the threshold hypothesis and the Bilingual Executive Advantage Hypothesis (BEA), which have

served as a foundation for investigating the potential relationship between bilingualism and working memory. The threshold hypothesis implies that competency in a second language can provide cognitive benefits that improve executive functions such as working memory; whereas the BEA undoubtedly states that bilingualism provides such benefits due to the neuroplastic nature of the human brain.. Throughout this chapter, we have mentioned the relevant definitions and explored the theoretical foundations supporting the positive effects of bilingualism on working memory. We also provided an overview of WM Baddeley's model, stressing on working memory identification and discriminating abilities as measured by stimulus recognition and reaction time. Additionally, we reviewed previous studies on the topic at hand. By addressing these aspects, we have laid the groundwork for further investigation on the relation between bilingualism and working memory. In the following chapters, we will delve deeper into empirical studies, methodologies, and findings that contribute to our understanding of this intriguing subject.

Chapter Two

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Chapter Two: Methods and Procedures

Introduction

The current study aims at examining the possible effects of bilingualism on working memory performance among Medea University students. To render this possible, we have selected to investigate this phenomenon via an exploratory case study. Undoubtedly, this research is descriptive in nature in which researchers have to report the results of participants' performance in cognitive tasks testing the working memory capacity. The population has undergone a systematic sampling procedure rather than a randomized one to assure the reliability and validity of the study findings. Similarly, while most previously conducted studies manifested a methodological gap in the sampling procedure; our study has opted for a more systematized and ordered sampling to avoid the interference of other external factors that might influence our participants 'performance. To make this feasible, a bundle of tools was used to conduct this exploratory research. First, the test subjects were selected based on a preliminary questionnaire addressing their linguistic and social background, as well as an online proficiency test for the bilingual population that determines their listening and reading skills. After that, we initiated testing the WM performance through two tasks designed specifically for that purpose. The first task (2 Back Task) was addressed to measure the verbal working memory performance, followed by a second task to determine the visuospatial sketchpad capacity. The obtained data was analyzed quantitatively by using the Statistical Package for the Social Sciences (SPSS) software alongside ANOVA1 to analyze the prerequisite participants 'data. All in all; this chapter will elucidate the methodology opted by the researchers to pilot the study.

2.1 Research Questions

The effect of bilingualism on the human mind and cognition is not yet fully uncovered. This field of research still has not provided answers to the possible influence of speaking two languages on executive functions. Hence, this study was initiated to examine the effect of bilingualism on working memory in accordance with the following questions:

Research Questions:

1. Does language proficiency impact the discrimination ability of working memory?

2. Does language proficiency impact the identification processing of working memory?

2.2 Research Design

As an attempt to answer the research questions, we deliberately chose to pursue an exploratory case study as it appears to be the most suitable method to conduct this research. Given the purpose of our present inquiry; a quantitative-based method has been followed to analyze the obtained data in order to achieve statistical results that would serve the comparative aspects of the current study, examining the different working memory performance between the monolingual and bilingual samples. In this regard; a preliminary sampling pilot study has been executed to elect congruent participants who bestowed an adequacy parallel to the test requirements for the experimental aspect of this investigation. Pertaining to this point; two experimental computerized tasks were executed to investigate the impact of bilingualism on measures of working memory; namely, reaction time and identification process.

2.3 Setting

The present study took place in the English department at Yahia Fares University of Medea during the first semester of the academic year 2022/2023. Participants were recruited from their classes within their departments; where they were first observed. In total, we had 20 students participating in this study, 10 being monolinguals and the other bilinguals. Participants were expected to be free from any problems that could influence the study. Henceforth, students with hearing or vision problems or neurological instabilities were removed. The study focused on uncovering the differences between monolingual and bilingual individuals in terms of their working memory capacity. For this aim, we used two tests that targeted both verbal and non-verbal inputs. In this regard, we performed the n-back (2 back) and Corsi test on our participants within the university premises because it was a convenient place due to the matter of the availability of the participants.

This study was planned to explore the differences in working memory performance of bilinguals and monolinguals. Henceforth, it was necessary to work with participants with different language systems. The chosen population for this aim was constructed from one

hundred Medea University students (50 bilinguals and 50 monolinguals). Students between the age of 21 and 23 years old were recruited for this study. The monolingual group consist of students from the department of Arabic Studies while the bilinguals are from the department of English Studies. Bilinguals were categorized into two distinct subs -groups composed of high proficient bilinguals (HPB) and low proficient bilinguals (LPB). They were filtered out through undergoing an online proficiency test called "EF set" through a set of questions that targeted mainly the skills of listening and reading. In order to attain a homogeneous sample for this study, our objective was to ensure that participants met specific criteria. To achieve this, we employed the Language and Social Background Questionnaire (LSBQ) to identify and exclude subjects who did not meet the specified criteria sought after by the researchers. That is to say, bilinguals with higher Arabic influence and monolinguals with English influence were excluded. We ultimately decided on a sample comprising 10 monolingual and 10 bilingual participants.

2.4 Sample and Sampling Procedures

To fulfill the goal of this study, the initial sample went through a non-randomized process that purposefully filtered out and excluded participants who did not meet the study standards. 20 third year students of Yahia Fares University were eventually selected to be the final participant's sample. Participants were recruited through classroom announcements where we went in order to ask for the participants' consent so that they could form a population. Then, we distributed a formula of the LSBQ questionnaire to gather information about their linguistic and social backgrounds. From this stage onward, we began the process of selecting a sample by excluding students who did not meet specific criteria such as being younger than 21 and older than 23 years old, to ensure that all participants are in approximately the same range of cognitive development. Furthermore, individuals with certain medical conditions like hearing, vision problems, or the inability to understand the language of the questionnaire were eliminated. Students from the English department were asked to perform an online proficiency test called "EF SET" and send their test results. These results were used to separate low from high proficient bilingual participants. Through this process of selection, a population of 100 students was condensed into a sample of 20 individuals composed of 10 monolinguals and 10 bilinguals that we considered the final sample of our study. These students were called to partake in the Corsi and 2-back test; in which instruction and guidance were presented.

2.5 Instruments for Data Collection

There is an wide range of tools used in conducting academic research. Each research project requires a specific instrument, as it is not a haphazard process. Therefore, research instruments should be carefully selected in accordance with the aims that researchers want to achieve. In the current study, we opted for four different tools that align with our selected approach, which is a quantitative method. This selection allows us to thoroughly examine bilingualism and its potential associations with working memory, as well as provide a comprehensive analysis of the targeted phenomenon.

2.5.1 Language and Social Background Questionnaire (LSBQ)

In order to properly select participants for the current study, a questionnaire was delivered to third year undergraduate students of both the English and Arabic departments of Medea University. The questionnaire, originally designed by Ellen Bialystok in 2016, has been adopted by many researchers who have similar interests in bilingual studies. It consists of three sections. The first constituent contains demographic questions that are nominal in nature such as name, age, gender, and occupational status. Additionally, it encompasses other questions relevant to the eligibility of the working memory tests including questions about vision and hearing problems, mental or neurological disorders, and any health conditions requiring medications that could potentially influence the participants' performance. The second section focuses on the social background of the individuals. This explores the educational level and professions of the parents, as well as the linguistic environment in which the bilingual participants were raised. The third essential section contains two sub-parts that delve into the language background. First, participants were asked questions pertaining to language acquisition. They were required to list all languages they understand and speak, indicating the age and manner through which they acquired each language. In addition to specifying whether there have been any period during which they did not use a particular language. Moreover, they had to assess their proficiency level in their native language (Arabic) as well as their second and additional foreign languages. The assessment covered all four linguistic skills: listening, speaking, reading and writing, utilizing a scale ranging from zero (no proficiency) to ten (high proficiency). The second sub-part of the questionnaire contains ordinal questions that address language use behavior within their community. Participants answered questions concerning languages used during various life stages, starting from infancy up to their high school years. After that, they had to indicate the languages they

used while talking to people in their immediate environment. Finally, participants were asked about the languages they use in different situations and activities, such as social media use, extracurricular activities, religious and social events. The questionnaire also included a question on the frequency of code-switching.

2.5.2 The 2back Task

The N-Back task is a widespread paradigm of working memory that is used extensively in the related literature. The N-Back task was first created by Kirchner (1958) to assess working memory capacity and cognitive control. Both bilingual and monolingual participants were shown a series of stimuli one at a time. Participants must determine if the current stimulus matches the stimulus that was provided N trials ago for each stimulus. N could be one trial, two trials, three trials, etc. The task gets increasingly challenging, as the longer the trials the more difficult it becomes to recall the targeted stimulus. We opted for 2-Back task, since it was most moderate in terms of difficulty. The stimuli in the current task are represented in Latin alphabet, specifically including letters A,B,C,D,E ,H,I,K,L,M,O,P R,S, and T. The total stimulus set consists of 15 stimuli (letters). The overall task had three blocks, with each block consisting of 25 trials, with The first one intended a as a training block for participants to familiarize themselves with the task. While in the two subsequent block, the data was saved and collected. The first training block shows the previous two stimuli, which helps the participant to learn the task. However, starting from the second and third blocks, the stimuli are hidden as they are to be memorized by the participant. Other variables that appear to affect performance include the presentation speed and the number of stimuli. For the speed, the task is designed as follows: each stimulus is presented for maximally 760 milliseconds (ms); then there is an inter-trial interval of 2000 milliseconds (ms), that is, a new stimulus is presented every 2760 milliseconds. It is also necessary to mention that this task was computerized and it was accessible through the website “Psytoolkit”.

2.5.3 The Corsi Task

The Corsi task is a block-tapping task designed to assess visuo-spatial short-term memory span. The task was designed by Corsi (1972) and is available on the website “Psytoolkit ". In this task, there are nine on-screen blocks. The experiment starts when the blocks signal in a sequential order starting with two blocks. Then, participants have to tap the blocks with a mouse following the same order it appeared in. The sequence extends with each successful operation up to complete the ninth block. Yet, very few could reach this span. In a study

carried by Kessels and colleagues (2000), they found that healthy individuals have an average span of six blocks. That is, most people would score between five to seven blocks. In the implementation adopted for this study, the task starts with a sequence of two blocks. Once the sequence has been shown, participants hear the word “go”. They need to click on the blocks in exactly the same order and click on “done”. If that block turns green, it implies a correct answer, and if it turns red, it signals an incorrect answer. The Corsi block span is decided on the blocks of the participants with correct answers. If performed correctly, they move to the next higher number of blocks. If done wrong, they get one more chance. If they do it then wrong again, the score is given (the Corsi block span).

2.5.4. EF SET Language Proficiency Test

The EF SET is a free standardized online English test that assesses individuals' listening and reading skills. (English grammar and vocabulary) in which test subjects have to answer questions that target their English vocabulary knowledge and grammatical competence (i.e. English tenses, part of speech, conjunctions, and linking words). The test is bisected into two equal sections: 7.5 minutes for reading and 7.5 minutes for listening. That is to say, test subjects took a total of 15 minutes to estimate their proficiency level according to the guidelines set by the Common European Framework of Reference (CEFR). Starting with the reading part, a “filling the gaps” task appears, in which participants are presented with 10 grammatical sentences to complete with the appropriate word or phrase from a variety of 4 suggested options. Following the completion of this step, the listening test begins. A series of 10 conversational audio recordings are presented consecutively during the listening test. The audio does not exceed the duration of 10 seconds. Participants will hear the first segment of the conversation and are asked to select the optimal response to what has been heard. They are restricted to play the recording 2 times only. In order to determine the proficiency level; the tester classified the level of proficiency based on the combined score of both listening and reading tests. It was estimated that individuals with a score ranging from 0 to 60 % were considered to be beginners. Those who scored from 61% to 85% are to be intermediate or low proficient. Participants with the highest score of 86% up to 100% were considered advanced or highly proficient.

This test was adopted in order to validate our participants’ proficiency level and confirm their self-assessment mentioned in the LSBQ questionnaire as an attempt to reinforce the validity of this research.

2.6 Data Collection Procedures

Our research adopted an exploratory quantitative case study on the effect of bilingualism on working memory. To this end, we decided to involve the participants through three main study measurements including: the LSBQ questionnaire, the N-back test, and the Corsi task, in order to collect measurable data prior to investigating the effect of bilingualism on working memory. At the start, researchers working on this dissertation went to both departments of Arabic and English studies where students were verbally informed about the need for their participation in the study.

- **A Semi-Pilot Study :**

Before engaging in the actual data collection required for this study, a semi-pilot study has been conducted to elucidate any ambiguous or challenging part that we might encounter in the used tools. 6 students (both bilingual and monolinguals) have answered the LSBQ questionnaire to subsequently undergo the 2back and Corsi tasks. On one hand, a detailed explanation was made for each question in the LSBQ questionnaire with emphasis on questions that have a direct influence over the main research questions. On the other hand, we explained the 2-Back test and performed it in front of the participants individually. Then, they proceeded to do 3 trial blocks to understand the test. Upon obtaining their results; the data has been moved to the SPSS software and statistical results were made. The same procedure has been followed with the testing of the Corsi task. All in all; the participants seemed to find no difficulty in understanding the experiment phases as the tools were well-constructed, direct, and clear.

2.6.1The LSBQ Questionnaire:

The language and social background questionnaire was administered to 100 students, in which it addressed some key information about its holders. For this, we explained some of the questions and provided assistance throughout this task. The questionnaire comprised three main parts. The first part held demographic data; that was maintained via questions like age, gender, and occupational status. These questions helped with the selection of the participants according to their gender (5 females and 5 males) for each as well as questions that provided data linked to the physical intelligibility of the participants or any physiological impairments; in which participants with vision and hearing problems or any neurological issues were to be excluded. The second part was geared to the social and educational background of the

participants. In this part, the focus was on the educational and professional level of the parents known as social educational status (SES). i.e., to investigate the number of languages they spoke and the number of languages used at home. This latter gave information about the linguistic environment of the participants; specifically, bilinguals with parents of a bilingual background. The third section contained questions about language background. In this section, participants provided valuable data about the age around which they learned the given number of languages they could speak and understand. Also, this section contained a part in which they had to assess their native and second language proficiency level in terms of the four skills of language; speaking, reading, listening and, reading using a scale from 0 that represents no proficiency up to 10 representing high proficiency. After that, they moved to the final section that investigated language use within the community. Data was gathered on the different possible contexts and the possible languages used in different contexts like home, school, social activities, or in activities such as: reading, texting, or browsing the internet, in addition to the number of those who took part in using the language including family and friends.

2.6. 2. The 2-back and Corsi Tasks:

These tasks were provided to the students through laptops in which they were asked to perform the tasks where the data was saved. We explained the rules of these tasks to the students and provided a training trial for each individual because we noticed that it was helpful to understand how the tasks runs. Afterward, the data was saved in the laptops so as to be later incorporated into “SPSS” tool for statistical analysis. We provided guidance throughout the whole process. It is also important to note that we took into account all the ethical considerations from privacy to confidentiality during the process of gathering and collecting this data.

2.7 Data Analysis Procedures

Two types of data were collected for this research to be carried out. Pre-investigative data was collected through a questionnaire and proficiency test, while ordinal task-related data that is prior to pursuing the research questions was collected via experimental working memory tasks. The aggregated data have been quantitatively analyzed using a couple of research tools. The Statistical Package for the Social Sciences (SPSS) software and Anova1 have been used.

2.7.1 Pre-investigative Data

- **LSBQ Questionnaire:** Participants' answers of the dichotomous questions concerning early and late bilingualism, alongside the context of acquisition and language use were emphasized in this analysis. The aforementioned data were analyzed using the SPSS in which they were assigned into frequencies, percentages through the use of the descriptive statistical function. The mean age of acquisition and situational bilingualism related answers were also retrieved to be used in comparative tables afterwards.
- **EF SET Proficiency Test**: test results were saved directly from the website and were manually double-checked with the questionnaire question that addressed self-assessment of language proficiency in the second language. Therefore; participants were divided into two equal groups: low proficient bilinguals and high proficient bilinguals. It is important to note that this step concerned restrictively the bilingual sample.

This step is especially necessary to pin down a framework for this study sample. The obtained results are to be used in the comparative analysis of the external factors guiding the working memory performance.

2.7.2 Working Memory Tasks Data

- **The 2back Task:** the data obtained from the website *"Psytoolkit"* have been transferred to the software SPSS to be treated as required. We selected the relevant data that served the research questions which are illustrated through the reaction time, the score (correct match, wrong match; missed match) that determines the individual's ability to identify selected stimuli (targeted letter identification) and to discriminate similar letters taking into accounts the response speed accuracy. These numerical data have been grouped in the SPSS as dependent variables for the mean value to be calculated. First, percentages of correct and incorrect scores of each participant were extracted. After that, we calculated the mean value for each categorical group starting with the within-group comparison (high versus low proficient bilinguals), then moving to the overall between-group comparison (monolinguals versus bilinguals).

- **The Corsi Task:** Using the Corsi task; the identification process has been tested. The data acquired from "*Psytoolkit"* have also been incorporated into the SPSS to measure the span of the Visuospatial WM capacity. We converted the score of correct and incorrect matches into percentages to make the comparison more approachable. These percentages were calculated again as a mean value for each group to be interpreted in relation to the existent threshold determined by previous research that is set to be a span of 6 blocks. Upon obtaining the aforementioned statistical data; a holistic analysis has been made. The researchers combined both pre-investigative data together with the working memory tests data and were organized to attain a comprehensive analysis of the mean value for these different variables. This has been possible through the use of One-Way Analysis of Variance (ANOVA) that is to determine the existence of any significant difference that appears between monolingual participants and their bilingual counterparts. The same ANOVA has been used to verify the difference between high and low proficient bilinguals regarding their working memory performances and the relation of their linguistic and social background to that performance.

Conclusion

Finally, this chapter described the method that was used to investigate the association between bilingualism and working memory performance among Medea University students. A systematic sampling approach was utilized to assure the study's reliability and accuracy, with participants completing a preliminary questionnaire (LSBQ) and an online proficiency test (EF SET). The data was analyzed using the Statistical Package for the Social Sciences (SPSS) software and ANOVA1 to assess verbal (2back task) and visuospatial working memory skills (Corsi task). This study aimed at the avoidance of external variables that can impact participants' performance by resolving methodological inadequacies noted in earlier studies and adopting a more structured sampling procedure.

CHAPTER THREE

DATA ANALYSIS

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CHAPTER THREE: DATA ANALYSIS

Introduction

This chapter presents the analysis procedure of the data that was collected through the language and social background questionnaire, the EF English test, and the 2-Back and Corsi WM tasks. The interpretation of the findings will then serve to fulfill the objectives of the present study. The analysis focuses primarily on the results of the 2-back task and Corsi task. The obtained results were calculated through the statistical package for the social sciences (SPSS) in terms of the mean values and percentages. In addition, a one-way ANOVA was used to compare the WM tasks' performance of the different language groups in a more efficient way. As a last step, we assessed the association between WM tasks results and the bilingual experience. The findings were then presented in histograms and scatter plots, along with a verbal description of the comparisons.

3.1 Section One: Sample Categorization

3.1.1 Sample Matching

Since the present study was undertaken for the main purpose of investigating the difference in WM between bilinguals and monolinguals. Factors like age, gender, and level of education were all matched when selecting the population to the best of our abilities. As demonstrated in Table 1, the results of the LSBQ show that the mean age of both monolingual and bilingual participants is 21 years old. Both groups consisted of 5 females and 5 males, share the same educational level, and are third year languages university students (see Appendix D). Linguistic and social background details were collected to give more insight into the participants' backgrounds.

In addition, Questions from 5 to 10 that assessed hearing, vision, physical disabilities, and mental disorders were all utilized to make sure all of the participants didn't have any impairment that could affect their performance in the working memory tasks.

3.1.2 Language Categorization

To decide on the participants' Bilingual state, two means of categorization were used: the language and social background questionnaire (LSBQ) and the EF Standardized English Test.

3.1.2.1 Results of the Questionnaire on Bilingualism

Question 1: Relative to a highly proficient speaker's performance; rate your proficiency level on a scale of 0-10 for the following activities conducted in Arabic and your other language(s).

Table 1

Proficiency Level of Monolingual and Bilingual Participants

Rate your proficiency level on a scale of 0-10 for the following activities conducted in Arabic and your other language(s).				
	Bilingual	Monolingual		Total
N participants	10	10		20
Scale (0-10) on Arabic L1 and L2	-	7 only spoke Arabic	3 got less than 20% in French	-

The participants were first classified into bilinguals or monolinguals based on their responses on the LSBQ. They were classified as Bilingual if they reported 50% or higher proficiency in speaking, understanding, reading, and writing in both Arabic and English. While they were classified as monolingual if they reported 50% or greater proficiency in Arabic and 20% or lower proficiency in their second language. 7 out of the 10 monolinguals reported that they only spoke Arabic with no background in a second language, while 3 of them reported lower than 20% proficiency in French (see Table 1, Appendix C).

3.1.2.2 Results of the EF Standard English Test

Table 2

EF SET Scores Results

Measures	Highly proficient Bilingual	Low Proficient Bilingual	Total

Mean EF SET Score (%)	89	73	167

The bilingual participants were further categorized as high proficient or low proficient based on their performance on the EF SET. The test has a standard classification of the performance that is based on a scoring system that divides the results into 6 classification levels. Since all of the participants' scores fell into the C2 proficient category (score of 71-100), we further categorized them as highly proficient if they scored 85 or higher on the test, and less proficient if they scored less than 85.

3.2 Section Two: Results of the Questionnaire on Background Measures

The rest of the questions in the LSBQ could not be taken into consideration when selecting the sample due to the study's limitations. Thus, they were used to compare monolingual and bilingual participants or highly proficient and low proficient bilingual participants according to the nature of the question.

Question 2: Do you play video games?

Table 3

Video Gaming Frequencies

Do you play video games?				
		Frequency	Percent	If **yes**, Mean hours they play per week
Bilingual	Yes	7	70.0	8
	No	3	30.0	-
	Total	10	100	5
Monolingual	yes	2	20.0	5
	No	8	80.0	-
	Total	10	100	5

Table 3 indicates differences between monolingual and bilingual participants in terms of their video gaming frequency. Bilingual subjects reported a higher frequency of playing video games in comparison to their monolingual counterparts. 70 percent of bilinguals stated that they play

video games with a mean frequency of 8 hours per week. In contrast, only 20 percent of monolinguals have the habit of video gaming with a frequency of 5 hours per week.

Question 3: Please indicate the highest level of education for each parent:

Table 4

Educational Background of the Bilingual Parents

Please indicate the highest level of education and occupation for each parent				
Bilingual	Father		Mother	
	Frequency	percent	Frequency	Percent
No high school diploma	1	10	4	40
High school diploma	2	20	2	20
Graduate or professional degree	7	70	4	40

Table 5

Educational Background of the Monolinguals' Parents

Monolingual	Father		Mother	
	Frequency	percent	Frequency	Percent
No high school diploma	7	70.0	9	90.0
High school diploma	1	10.0	1	10.0
Graduate or professional degree Occupation	2	20.0	0	0.0

The two tables above demonstrate the level of education of the parents of the participants. A significant difference can be observed between the two groups' answers. 70% of the fathers of bilinguals have a graduate degree, while 20% of monolinguals' fathers have it. Similarly, 40% of the bilinguals' mothers have a graduate degree while none of the monolinguals' mothers have a graduate degree.

Question 4: Were you born in Algeria?

All participants were born and raised in Algeria

3.3 Section Three: Results of the Questionnaire on the Bilingual Experience

Only the answers of the bilingual participants were taken into account for this question, since all participants started acquiring their native language (Arabic) at birth.

Question 5: a- List all the languages and dialects you can speak and understand including Arabic, in order of fluency.

b- At what age did you learn it? (If learned from birth, write age "0")

Table 6

Age of L2 Acquisition

At what age did you learn it? (If learned from birth, write age "0")					
Measures	Highly proficient bilingual		Low proficient Bilingual		Total
Mean age of English acquisition	9		10		19
category	Late Bilingual	Early Bilingual	Late Bilinguals	Early Bilingual	-
Frequency	3	2	4	1	10
Percent	60%	40%	80%	20%	100

The data on the age of acquisition of L2 was used to classify the participants as either early or late bilinguals. They were categorized as early bilinguals if they acquired English before the age of 8, and late bilinguals if they acquired it after the age of 8. The results, as demonstrated in the table above, show that two participants from the highly proficient group fell into the early

bilingual category, while only one of the low proficient groups did so. Additionally, both highly proficient and low proficient bilinguals had an average age of acquisition of 9 years old and 10 years old, respectively, which, indicates that the mean age of both groups put them in the late bilinguals category.

Question 6: Please indicate which language(s) you generally use when speaking to the following people.

Table 7

Situational Language Use of HPB and LPB

Please Indicate Which Language(S) You Generally Use In The Following Situations.				
Participants		Friends	Siblings	Parents
Highly Proficient Bilinguals	Frequency	5	4	1
	percent	100	80.0	20.0
Low Proficient Bilinguals		Friends	Siblings	Grandparents
	Frequency	5	1	1
	percent	100	20.0	20.0

Both highly proficient and low proficient bilinguals use their L2 to talk with their friends, while 80% of the highly proficient use it with their siblings. Only 20 % use it to speak to their parents.

Question 7: Please indicate which language(s) you generally use in the following situations.

Table 8

The 3 Situational Contexts with the Highest English Use

Please Indicate which Language(s) you Generally Use in the Following Situations.				
Participants		Extracurricular activities	work	Social Activities
Highly Proficient Bilinguals	Frequency	5	4	4
	Percent	100	80	80
		School	Social activities	Extracurricular Activities
Low Proficient Bilinguals	Frequency	5	4	2
	Percent	100	100	40

A question on language use was to assess how often the bilingual participants use English in different situations. English usage was considered to be present if it accounted for half or more of the total language use. Table 8 presents the findings regarding the situations in which highly proficient and low proficient bilinguals predominantly use English. Highly proficient bilinguals use English the most in the workplace, social activities, and extracurricular activities, with the latter showing the highest frequency of English use. Meanwhile, low proficient bilinguals primarily use English during social activities, work, and extracurricular activities, with the latter two having the highest levels of English use.

Table 9

Mean Frequency of Situational L2 Use

The Frequency of L2 Use in the listed situations.		
Participants	Highly Proficient Bilinguals	Low Proficient Bilinguals
Mean Frequency of Situational L2 Use n= 8	5	3
Percent	62.0	38.0

In addition, more data from the same question were collected on the number of situations in which highly proficient and low proficient bilingual participants used English 50% or more of the time. As the table above demonstrates, highly proficient bilinguals had a greater tendency to use English in more situations than low proficient bilinguals. They utilized it in an average of 5 out of 8 different situations. Meanwhile, low proficient bilinguals utilized English for an average of 3 situations.

Question 8: Please indicate which language(s) you generally use for the following activities.

Table10

The Frequency of L2 Use for Personal Activities

The Frequency Of L2 Use In The Listed Personal Activities.		
Participants	Highly proficient Bilinguals	Low Proficient Bilinguals
Mean Frequency of L2 use (n= 8)	8	6
Percent	100	75.0

The table above shows that all of the highly proficient bilingual participants used their L2 for more than 50% of the time in all the 8 activities listed (reading, email, texts, social media, notes, TV, movies, and browsing the internet). Meanwhile, low proficient bilinguals used their L2 in an average of 75% of the listed activities, as only one participant used his second language in all 8 activities.

Question 9: Please indicate how often you engage in language-switching.

Table11

Frequency of Code-Switching

Please indicate how often you engage in language-switching					
Participants		rarely	sometimes	frequently	always
High Proficient Bilinguals	Frequency	1	1	2	11
	mean	0.2	0.2	0.4	2.2
	percent	4	4	8	44
Low Proficient Bilinguals	Frequency	1	7	6	4
	mean	0.2	1.4	1.2	0.8
	percent	4	28	24	16

Table 11 indicates the frequency of code-switching for both low and highly proficient bilinguals. HPB group showed a frequency of 2.2 of constant code-switching. That is, 44% of HPBs tend to code-switch more often. Likewise, only 16% of the LPB group reported a constant code switching process. 28% of them reported frequent code-switching.

3.4 Results of the Working Memory Tasks

3.4.1 Task 1: 2-Back

The mean scores of the identification and discrimination data were divided and categorized along the monolingual and bilingual participants. Then it was further divided into highly proficient and low proficient bilinguals in order to assess whether the degree of language proficiency had any impact on the task performance, as it is demonstrated in Table 2. During the 2-Back task, participants can accurately identify stimuli, fail to identify stimuli, correctly reject stimuli that are false, or incorrectly identify a stimulus that is false. These four types of responses are combined in a score of correct responses and it serves as the identification variable. Along with the correct score, the reaction time of each trial was recorded, and its mean values are regarded as the discrimination variable. Data analysis was carried out through two phases: first to compare the bilingual versus monolingual performance, then to compare high proficient versus low proficient bilinguals. In both analyses, the accuracy score and mean RT were analyzed using a one-way ANOVA.

Bilinguals versus Monolinguals

Table 12:

Bilinguals and Monolinguals' Mean Accuracy Scores and RT in the 2-Back Task

Measures	Bilingual	Monolingual	Total
Accuracy Score (%)	88	79	167
RT (ms)	1151	2073	3224

Figure 1:

Difference between Bilinguals and Monolinguals' Accuracy Score for 2-Back Task

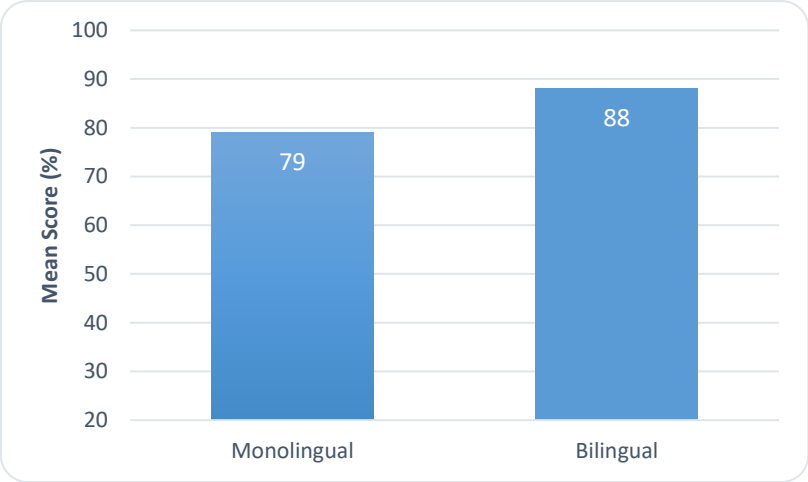
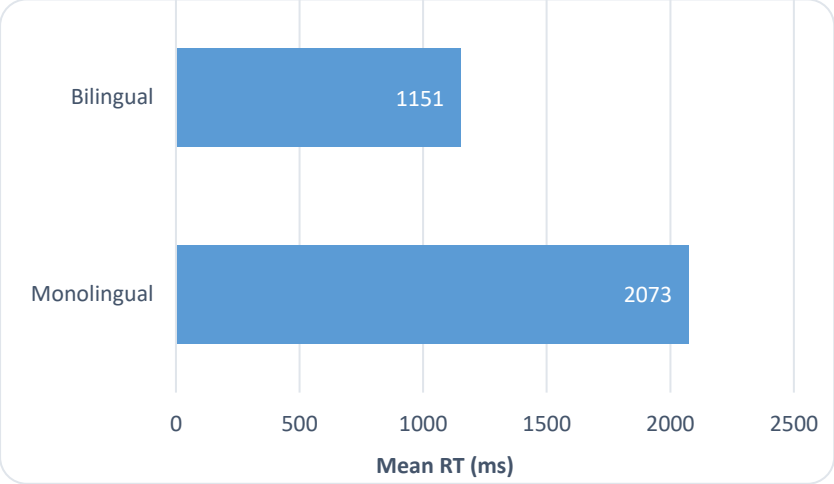


Figure 2

Difference between Bilinguals and Monolinguals' RT for 2-Back Task



As Table 12 demonstrates, language (bilingual versus monolingual) was selected as the factor variable, with the correct score and RT as the dependent variables. For the correct score, the F-value = 4.358 is higher than the critical F of 3.883, which suggests that there is some difference between the bilinguals and monolinguals score; however, the p-value being 0.051 is only marginally above the common threshold of $p = 0.05$. This indicates that the observed difference is not statistically significant, and it suggests that the difference in accuracy scores between the groups may be due to chance. As for reaction time, the combination of the large F-value of 125.061 and $p < .001$ suggests that there is a substantial difference between the two groups. This means bilingual participants performed the task significantly faster compared to their monolingual counterparts.

Highly Proficient versus Low Proficient Bilinguals

Table 13:

High Proficient and Low Proficient Bilinguals' Mean Accuracy Scores and RT in the 2-Back Task

Measures	Highly proficient bilingual	Low proficient Bilingual	Total
Accuracy Score (%)	87	88	175
RT (ms)	1146	1156	2302

Figure 03:

Difference between Highly Proficient and Low Proficient Bilinguals' Mean score

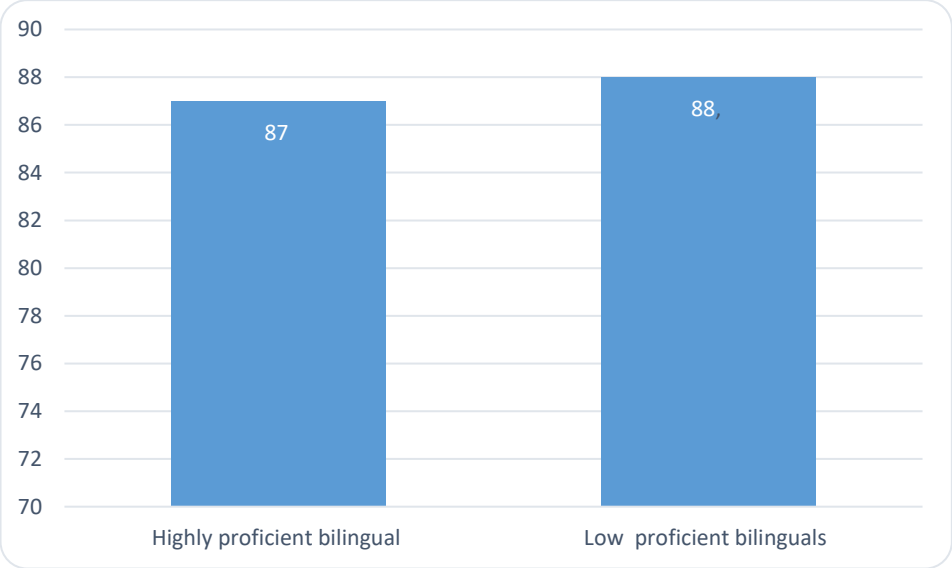
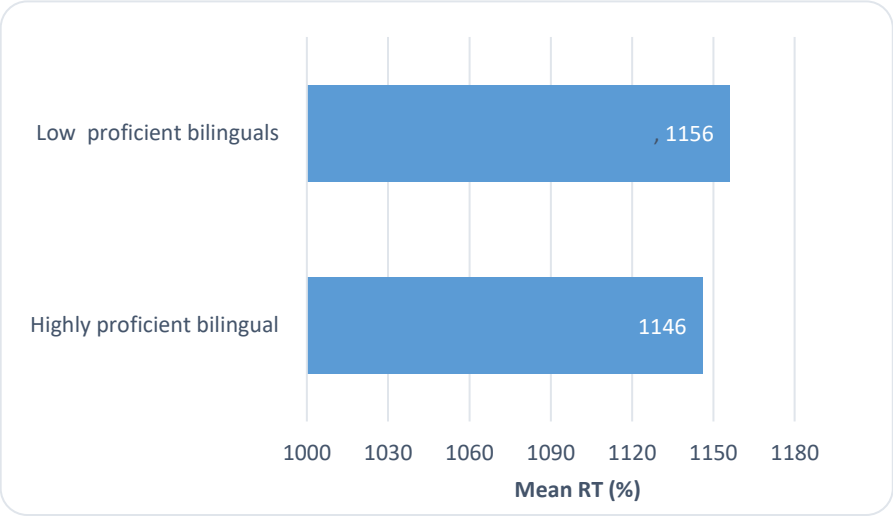


Figure 04

Difference between Highly Proficient and Low Proficient Bilinguals' RT for 2-Back Task



In a second analysis, the factor variable selected was highly proficient versus low proficient bilinguals. For the correct score, F= 0.040, p= 0.846 > 0, 05. The low F value and higher P value both suggest that there is no significant difference between the high proficient and low proficient bilingual groups in terms of correct scores. As for mean RT, The F value = 0.041, and the p value = 0.845. Similar to the previous variable, the F value is too low and the p value is greater than 0.05, indicating no significant difference between the two groups in terms of response time.

3.4.2. Task 2: Corsi

The data collected through the Corsi task consisted of two key variables: First, The Corsi span, which is the primary result of the task. It served as the identification score, as it reflects the participants' ability to remember and identify the correct order of the spatial positions. The Second variable is the error-accuracy score. Similarly to the 2-back task, to explore possible differences in visuospatial WM performance between the language groups, a one-way ANOVA was used with language as the factor variable, and Corsi span and accuracy score as the dependent variables.

Bilinguals versus Monolinguals

Table 14

Bilinguals and Monolinguals' Mean Corsi Span and Accuracy Scores in the Corsi Task

Measures	Bilingual	Monolingual	Total
Cori Span	5.6	4.6	10.2
Accuracy Score (%)	59	56	115

Figure 05

Differences between Bilinguals and Monolinguals' Corsi Span for Corsi Task

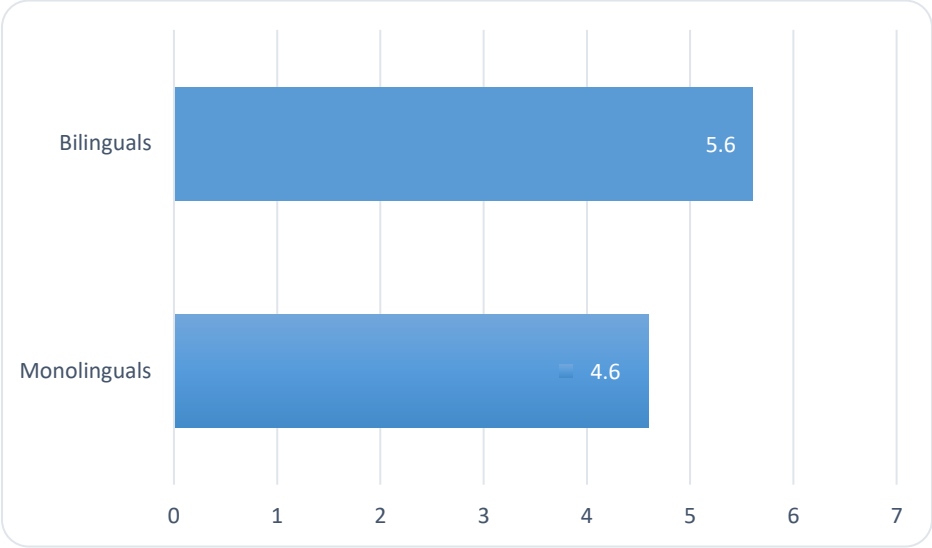
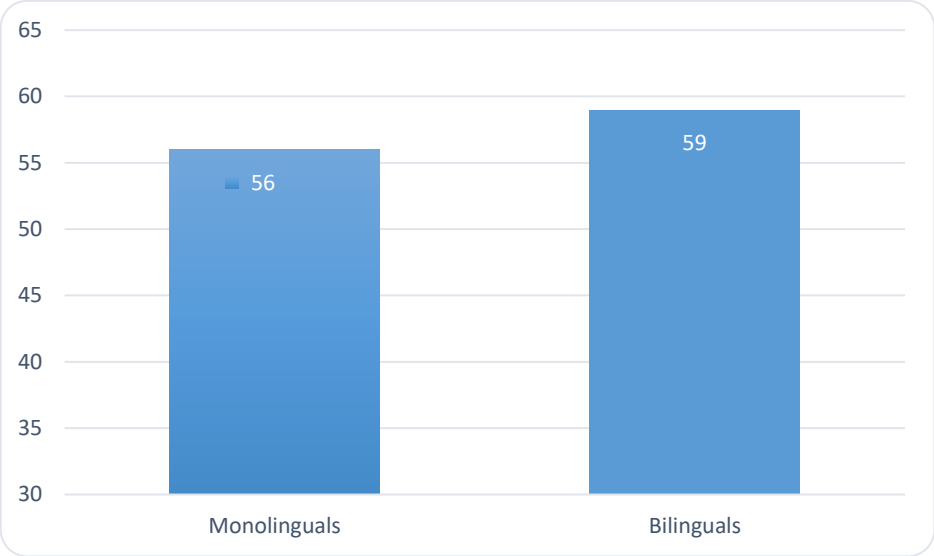


Figure 06

Differences between Bilinguals and Monolinguals' Accuracy Score for Corsi Task



In the first analysis, as Table 3 demonstrates, the mean values of the Corsi span and accuracy score of the bilingual and monolingual groups were selected as the factor variable. In the mean Corsi span, F-value = 3.25 is smaller than the critical F = 3.835. Thus, no significant difference can be concluded between the means of the two groups. Similarly, when considering the accuracy score, F= 0.193 < F (critical) = 3.912, the F value is too low to establish any distinction between the mean values. It is also low to the corresponding p value of 0.67 > 0 .05.

Highly proficient versus low proficient bilinguals

Table 15

Highly Proficient and Low Proficient Bilinguals 'Mean Corsi Span and Accuracy Scores in the Corsi Task

Measures	Highly Proficient Bilingual	Low Proficient Bilingual	Total
Cori Span	6	5.2	10.2
Accuracy Score (%)	56	59	115

Figure 07

Difference between Highly Proficient and Low Proficient Bilinguals' Corsi Span for the Corsi Task

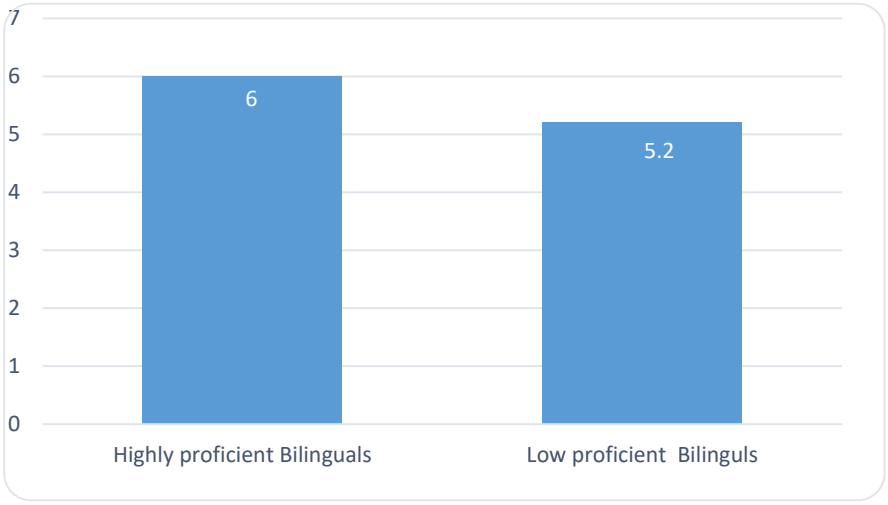
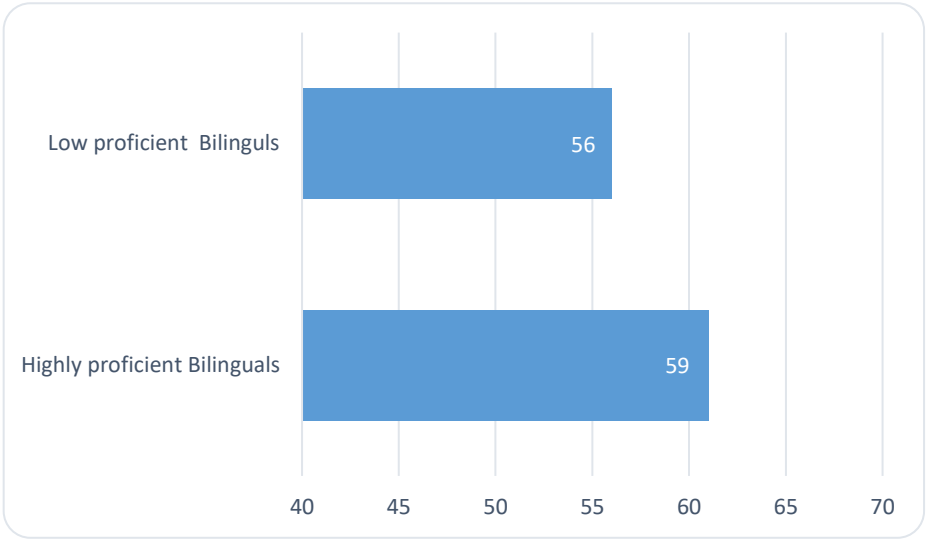


Figure 8

Difference between Highly Proficient and Low Proficient Bilinguals' Mean Accuracy Score for the Corsi Task.



In the second analysis, Table 4 shows that the considered factor was high proficient bilinguals and low proficient bilinguals.in terms of whether was there any difference in results between the two, one-way ANOVA revealed the following: For the Corsi span, F=1.882 and the associated p=0.207 > 0.05. Therefore, there is no significant difference between the Corsi spans of the two groups. As for accuracy score, The F value is only 0.619, and the p value is 0.454 > 0.05. Similar to the Corsi span, this indicates no remarkable difference between the two groups in terms of accuracy score.

3.5 Associations between bilingual experience and WM performance:

A number of scatter plots were used to investigate the potential relationship between the WM tasks' results and the different aspects of bilingualism. The independent variables we selected were the age of acquisition and the use of the second language (English), while the dependent variables were the identification and discrimination scores on the WM tasks. However, when it comes to the age of acquisition of the L2 variable, because 6 out of 10 participants had all acquired English when they were at the age of 11, the scatter chart could not provide valid association results (see Figures 4 and 5, Appendix D).

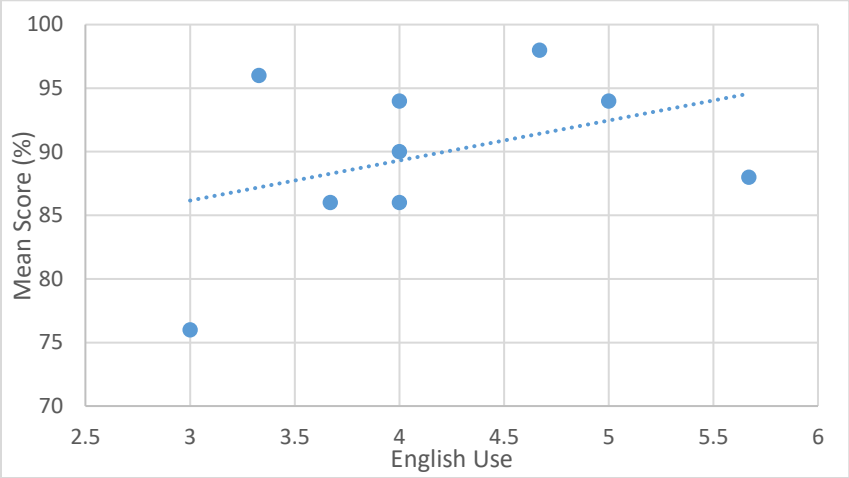
3.5.1 English Use and WM Tasks Results

In order to analyze the bilingual participants' frequency of L2 (English) use, we used the results of Questions 6, 7, and 8 from the questionnaire, since the three assess bilingual participants' L2 use in various situations, social interactions, and activities, respectively. We combined these three factors to create an overall L2 use factor. Through SPSS, a calculator that computes factor scores was used to obtain a measure of the degree of L2 Use. A composite score that represents the overall English usage was calculated for each participant. We presented the relationship between L2 use and WM tasks' identification and discrimination results in three scatter charts.

3.5.1.1 Relationship between English Use and Mean Accuracy score in the 2-Back Task

Figure 9

Relationship between English Use and Accuracy Score for the 2-Back Task

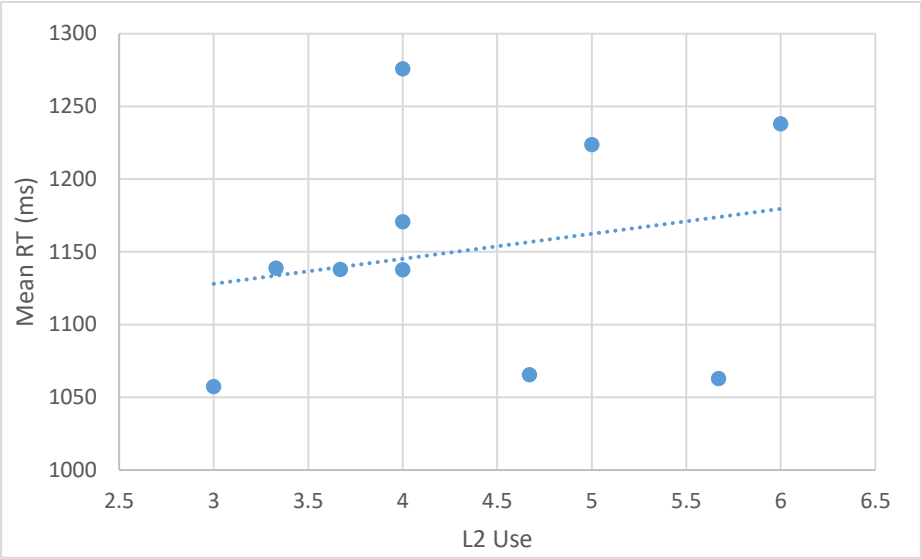


The figure above shows the regression line leaning slightly upwards. This suggests a positive relationship between L2 usage and reaction time that English use had a positive effect on the 2-back task accuracy score. The higher the L2 usage composite score the higher the mean accuracy score.

3.5.1.2. English Use and Mean RT in the 2-Back Task

Figure 10

Relationship between L2 usage and Mean RT for the 2-Back Task

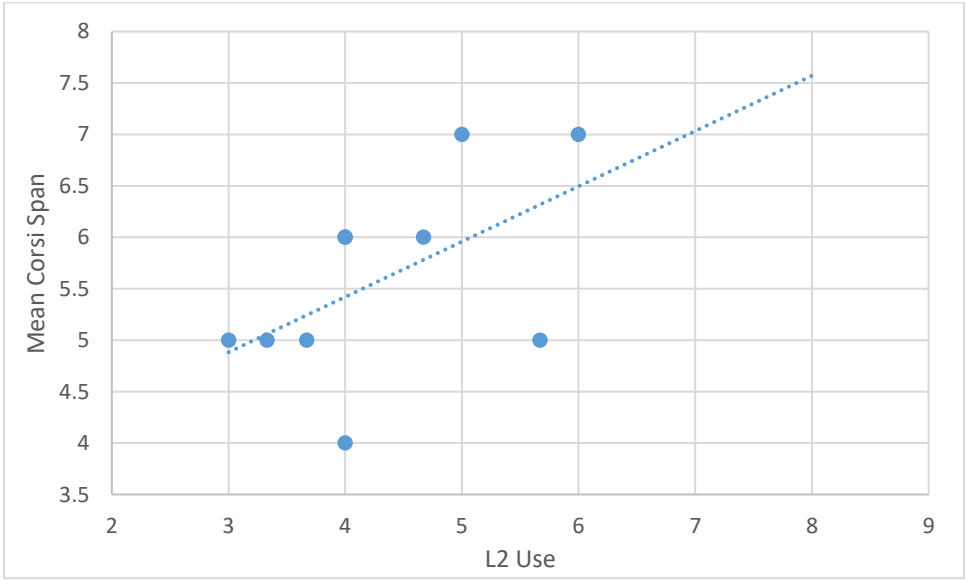


As can be observed in Figure 10, the regression line is leaning slightly upwards, while the data points are distributed far from the line. This suggests a positive, however weak relationship between L2 usage and reaction time. That is, the more the L2 usage composite score increases, the more there is a tendency for the reaction time to increase.

3.5.1.3. English Use and Mean Corsi Span in the Corsi Task

Figure 11

Relationship between L2 Use and Mean Corsi Span for the Corsi Task



The above figure shows that the line is leaning substantially upwards, while the data points are distributed close to the line. This suggests a positive relationship between L2 use and Corsi Span. In other words, the more the L2 usage composite score increases, the higher is the Corsi Span.

Conclusion

In this chapter, the data collected through the selected research study tools were presented and interpreted. First, we displayed the primary results of the LSBQ that were utilized to categorize the sample into bilingual and monolingual groups. Then, the results of the EF SET were used to further categorize the bilingual participants into highly proficient and low proficient bilingual groups according to how good their performance was in the test. Additionally, we described the findings of the other LSBQ questions that were not concerned with sample matching but gave more insight into the linguistic and social background of the bilingual participants. The findings included the age at which they acquired a second language and the most likely type of situations in which they utilized L2. Moving to the WM tasks results, we transferred the numerical data of the 2-Back and Corsi tasks from the website, selecting only the relevant results and arranging them in an SPSS data sheet, then the program was used to calculate the mean values and percentages of the identification and discrimination data. After that, we analyzed the difference between the different language groups' performance in the WM tasks through the use of one-way ANOVA, which served as the primary results that resolve our research problem. Finally, and as an additional insight into the bilingual experience, we used scatter charts to investigate the relationship between language use and WM tasks' performance.

Chapter Four

General Discussion, Implications and Limitations

Introduction

4.1 Discussions of the LSBQ Questionnaire Results

4.1.1 Monolingual Vs Bilinguals

4.2 Discussion of the 2back Task

4.2.1 Discussion of Monolingual VS Bilingual 2back Task

4.2.2 Discussion of High Proficient VS Low Proficient Bilinguals

4.3 Discussion of the Corsi Task

4.4. Association between Bilingual Experience and Working Memory Performance

4.5. Main Findings

4.5.1 The Effects of Bilingualism on Identification and Discrimination Ability

4.5.2 The Effects of Language Proficiency on Identification and Discrimination Ability

4.6 Research Implications

4.7 Research Limitations

4.8. Recommendations and Further Suggestions

Conclusion

Chapter Four: General Discussion, Implications, and Limitations

Introduction

This study places under investigation the effects of bilingualism on working memory abilities. Monolingual and bilingual third year students partake in two experimental tasks to measure their working memory capacity. Upon obtaining the results of the questionnaire adopted to match the sample of this study, and the results of the 2back and Corsi tasks that assessed both verbal and visuospatial working memory capacity respectfully; this chapter aims at providing a profound discussion of the results presented earlier with an in-depth explanation of the general findings. An association of the bilingual experience and working memory performance has been established for further understanding of their complex relationship. Furthermore, the chapter gives insight on the research implications alongside the study limitations that hindered our investigation. We also offered some further suggestions that could not be covered within the frame of this study to be a starting point for researchers who hold common interests in exploring the effects of bilingualism on working memory.

4.1. Discussions of the LSBQ questionnaire results

In order to get more insight on the relationship between WM performance and bilingualism, an in-depth investigation was conducted on each participant's language and social history through the use of language and social background Questionnaire. The responses were first used to categorize the participants into language groups, then to assess their linguistic and social background as continuous dependent variables, in addition to analyze how they correlate with their performance in the WM tasks. In this section, we will discuss the score of individuals who play video games and those who do not. This variable has been chosen as a common demographic status that is shared by both monolinguals and bilinguals. Linguistic background and proficiency level are to be discussed in a separate section as more fundamental variables.

4.1.1 Monolinguals versus Bilinguals

The question targeting video games is to identify the frequency of playing video games in order to discern any interplay between bilingualism and gaming as both experiences provide cognitive exercise for the brain. Hence, the question is to ensure that both groups are on an approximate level of cognitive development. The results we found manifest a

significant difference in which bilinguals had a higher frequency of playing video games. This correlates with the positive results of their performance on the verbal working memory task. In addition to video gamers' tendency to show an enhanced performance when dealing with cognitive tasks that require problem-solving and attention abilities, they also show enhancement in working memory capacity as reported by our findings (see Figure 1, Appendix D).

4.2 Discussion of the 2-back Task

The 2back task was used on both monolingual and bilingual students, alongside the high proficient and low proficient bilinguals.

4.2.1Discussion of Monolingual versus Bilingual 2-back Task:

The 2back task was utilized to test the verbal working memory performance of monolingual and bilingual participants. The results of the discrimination ability state that there is a significant difference between the performances of the two groups. The bilingual participants reacted to each trial in the task much faster than the monolinguals. That is, bilinguals have a better discrimination ability that enhances their overall working memory performance. When it comes to the results observed in terms of their identification ability. Bilingual average accuracy score was relatively higher than that of the monolinguals, i.e. they could successfully identify more targeted stimuli presented in the task. However, when looking at the one-way ANOVA results, it shows that the difference between the two groups is only marginal, and that it may be due to random chance or sampling variability rather than a significant difference in performance. This disparity of ANOVA not detecting significant difference despite the observed mean difference happens for reasons mainly related to the statistical power of the study. In the current study, the results are most likely due to the small sample size, as a sample of 20 participants limits the statistical power, which makes it harder to identify the smaller differences between the data. Thus, while this confirms that the study's results should be interpreted with caution and further research with a larger sample is needed to draw more definite findings, there is still a consistent pattern of the mean values that suggest the presence of an effect of bilingualism on the tasks' performance. These findings are in accordance with the theoretical foundation presented in the first chapter. These results support the claims of the BEA hypothesis in which an improved performance has been observed thanks to the enhancement bilingualism offers for working memory capacity. A previous research by Rodriguez-Fornells, De Diego, Balaguer, and Münte (2006) showed that

cortical regions responsible for general executive functions are activated and trained when resolving conflicts in language processing caused by interference from a non-target language during target-language production. This suggests that bilingual individuals possess additional cognitive resources and more efficient utilization of these resources when performing tasks that involve non-linguistic conflicts (Bialystok, 2008). As a result, bilingualism has been found to have a positive impact on executive functions, namely working memory, thanks to neurological approximations.

4.2.2 Discussion of High Proficient versus Low Proficient Bilinguals:

Unlike what we expected, there was no significant difference between low proficient and high proficient bilinguals in their verbal working memory performance. Therefore; it has been noted that language proficiency does not bear any influence over both identification and discrimination abilities of working memory. Given that the construct of language proficiency is a highly abstract concept, it remains elusive and challenging to capture or measure it empirically. In a similar research investigating differences between high and low proficient bilingual children, researchers reported a noticeable advantage of the highly proficient language group over the low proficient ones. That is, a positive relationship has been found when the targeted sample was composed of children but not so apparent in young adults. This could be an indication that the age difference affects the research findings. Prior research has shown that older adults had a greater bilingual advantage than younger adults (e.g., Bialystok et al., 2004, 2008a; Gold, Kim, Johnson, Kriscio, & Smith, 2004). Bialystok (2006) attributed this to the presence of a ceiling effect. Wang (2008) explained that the score limitation at the top of a scale is commonly termed the “ceiling effect”. The ceiling effect occurs when a task or measurement lacks sufficient difficulty or challenge for a specific group, causing scores to cluster near the upper limit of the scale. This clustering of scores at the top can obscure or hide potential differences or improvements among participants, making it difficult to identify significant effects or variations in performance.

Bialystok (2006) used simple and complex variants of the flanker task in a study of young adults. The study reported no difference between bilingual and monolingual young adult’ participants when the tasks were relatively easy. Easy tasks would result in faster reaction time (generally less than 500ms) which leaves little room for substantial group differences to appear above individual differences in performance. Contrary to this, complex tasks require slower RTs due to the effortful processing which is highly probable to reflect

group differences showcasing a bilingual advantage. The 2back task may not have been challenging enough for this particular age group, potentially leading to performance saturation at the higher end of the measurement scale. Previous research suggests that the advantages of bilingualism and language proficiency may be most evident in older individuals who engage in complex nonverbal tasks. Consequently, the cognitive benefits associated with language proficiency may not have been observable or quantifiable in this task. It is possible that the use of a complex version such as 3-Back or 4-Back tasks can address the ceiling effect as they employ more challenging and intricate measures to effectively capture the potential benefits of second language proficiency on working memory performance in younger adults.

4.3 Discussion of the Corsi Task:

According to the results obtained, there seem to be no actual differences in the visuo-spatial working memory performance of bilinguals and monolinguals alongside the low and highly proficient groups. The accuracy score, which is an indication of identification ability, showed no significant difference in the performance of monolingual and bilingual students. Although an amalgam of previous research reported an advantage of bilinguals in nonverbal tasks over tasks touching upon verbal working memory. Our results, however, do not seem to go in line with the general findings available in the literature. Nevertheless; one could see a minor superiority in the bilingual performance over that of the monolingual group. Bilingual participants demonstrated a mean value of the Corsi task with an estimated span of 6 blocks which is parallel to the threshold set for this task. The monolingual group exhibited a Corsi span of 5 blocks which is also close to the threshold of the span of average healthy individuals.

One possible justification for the insignificant difference found in this task could be the sacristy of the study population. The P value and F value found in the data analysis reflect no significant discrepancy in both the between-group and within-group distinction, as it needs a larger population to be apparent.

4.4. Association between Bilingual Experience and Working Memory Performance

Due to the small sample size, the scatter chart could not give valid association results. That is, Non-significant results in small sample sizes are more likely to be due to the limited statistical power than the lack of a true relationship. Nevertheless, we used a set of regression analysis graphs to engage in a visual analysis to draw initial insights through observing the

slope and linearity, in addition to comparing it with the results from previous studies that there is an examined similar variable. This allows seeing if a common trend to which the current study is leaning, and therefore generating hypotheses for further investigation. For the association between the participants' age of acquisition of L2 factor with the WM tasks performance, the regression analysis created for that could not be interpreted. That is due to the fact that our study aims at minimizing the socio-linguistic differences within the population. In addition, the context of the study being in an Algerian society also plays a factor, because while French is acquired from a very early age among many people, the common Algerian person gets in contact with English for the first time at school. So, while we selected Bilingual participants whose second language is English, the vast majority of them started acquiring English in the first year of middle school, which coincides with them being approximately 11 of age. Thus it is almost unavoidable for our participants to have had acquired English at very similar ages.

We calculated a composite score variable that combines 3 factors: (1) English Societal Use, (2) English Social Use, and (3) English Use in various activities. The score represents an overall contextual English use and was used to assess whether there is an observable relationship between the participants' English us and their WM tasks performance; in particular, the mean accuracy score and reaction time in the 2-Back task and Corsi span on the Corsi task. All three scatter charts showed a positive relationship between the two variables. We found that the higher the English use, the better the performance in the WM tasks. In more detail, English use had varying degrees of influence on the WM tasks, with the Corsi span showing the most substantial effect, to the Mean 2-back score that had a lesser degree of influence from English use, then the Mean RT which showed that the higher the English language use, the slower reaction time was recorded. The scatter chart of the RT results fall in line with a study by Capani (2019) that also found a positive influence of L2 social use and a slow reaction time in the n-back task.

In future research, focusing on a specific aspect of the bilingual experience to examine would give much more detail about the relationship between bilingualism and WM capacity. It might also help strengthen the BEA hypothesis to possibly identify the exact mental processes that affect and enhance WM the most, much more than drawing conclusions from comparing monolinguals and bilinguals only.

4.5. Research Main Findings

This study aims at identifying the effects of bilingualism on working memory performance. To answer this inquiry, we deemed it necessary to answer further sub-questions on the impact of language proficiency on two perceptual abilities utilized in working memory processing which are identification and discrimination abilities.

4.5.1 The Effects of Bilingualism on Identification and Discrimination Abilities:

The main aim of the current study is to investigate the impact of bilingualism on working memory performance. The route we opted for to answer this question was through measuring the identification and discrimination processes that are activated while engaging in working memory tasks. The findings of our results suggest that bilingualism has a positive influence on verbal working memory through enhancing both identification and discrimination abilities. Meanwhile, null results were reported on the influence of bilingualism on visuospatial working memory. Still, our findings provide additional support to the existing theories in favor of the bilingual advantage, as they validate the previously suggested hypothesis.

4.5.2 The Effects of Language Proficiency on Identification and Discrimination Abilities:

The construct of language proficiency had no remarkable difference in both identification and discrimination measures of working memory. Both the 2-Back and Corsi tasks showcased no significant discrepancies between highly proficient and low proficient bilinguals. Hence, neither the verbal working memory nor the visuo-spatial one seems to be affected by the degree of language proficiency. Henceforth, it is noted that the mere existence of a bilingual experience is enough to enhance working memory regardless of proficiency level.

4.6Research Implications:

The findings of our research have provided clear insights and understanding of the relationship between bilingualism and working memory. These findings have paved the way to draw conclusions on how bilingualism can be inserted in our world and what are its implications in both practical and theoretical frames.

- Understanding how bilingualism positively affects working memory performance will help educators promote bilingual education programs and find strategies to maximize learning outcomes for individuals with bilingual backgrounds.

- In the clinical context, our research adds to the development of interventions for individuals with cognitive impairments or working memory deficits. Understanding the bilingual influence on working memory performance can help creating targeted rehabilitation programs.

- This study contributes to the Bilingual Advantage hypothesis debate. It is a further addition to the existing theories that support the positive influence of bilingualism on working memory.

- Getting a closer look into the phenomenon of bilingualism and its impact on cognitive abilities will shed light on the necessity of language diversity that will have an effect on the preservation of bilingualism in communities. By recognizing and valuing bilingualism, communities can foster a more inclusive environment that embraces different languages and cultures.

- This acknowledgement of language diversity can have positive social, cultural, and economic implications, promoting multiculturalism and enriching societies

4.7Research Limitations

The present research was conducted with the aim of figuring out the possible effect of bilingualism on the capacity of working memory. To get near this goal, a set of tasks were performed on two main different categories of university students. Yet, we pointed out some limitations and delimitations.

- The investigation of the relationship between bilingualism and working memory falls within the longitudinal type of studies due to its nature. Our goal was to conduct this study continuously over time, in order to incorporate a large sample of participants. Unfortunately, as master's students, we lacked the necessary time to execute such processes, as they are time-consuming and require thorough verification and detailing of the essential elements in this research.

- we leaned towards using an Arabic version of the tasks performed on the monolinguals, as speakers of the Arabic language composed of full word units -instead of single letter units-. However, due to technical ignorance of the algorithms and digital coding that runs the tasks, we were left with the present tasks, which were composed mainly of single Latin letters for both categories of participants.

- We were unable to access eye-tracking tools that could have measured participants' movements and facial expressions during task performance. This additional data would if interpreted provided insightful information and clues regarding our findings.

- The validity of the proficiency test among bilinguals was a genuine concern, particularly in the context of online services. Specifically, there were concerns regarding the lack of guidance and control, testing environment, as well as the authenticity of the language performance required during the testing procedures.

- Another issue appeared while working on the literature review section. we encountered difficulties in accessing information from the original sources we were obliged to rely on secondary resources due to the requirement of payment for accessing the original ones. Furthermore, there was a dearth of available data pertaining to the field of working memory. Although we had access to SNDL (The National System of Online Documentation), the number of books, academic articles, and journals was limited.

- Regarding the language of the monolingual participants, our study faced a lack of homogeneity in Arabic participants, considering their diverse environment and the fact that they spoke the Algerian Arabic dialect, which we considered the language of the monolingual participants. Additionally, the integration and influence of the French language within the Algerian society posed challenges in eliminating participants who spoke or understood French. It is worth noting that the French language is deeply entrenched in society, making it difficult to exclude individuals with exposure to it.

4.8Recommendations and Further Suggestions

- Longitudinal Studies: Performing longitudinal studies that monitor the cognitive progress of bilingual individuals over an extended period would offer valuable insights into the relationship between bilingualism, working memory, and executive functions. Such research would provide valuable information on the enduring impacts of bilingualism on cognitive abilities, particularly in relation to working memory.
- Age Effects: Investigating the impact of age on the relationship between bilingualism and working memory through examining the cognitive abilities among people who acquire bilingualism at different life stages, such as early childhood, adolescence, and adulthood, will help subsequent research overcome the challenges we face when dealing with a single categorical group (ceiling effect). As a result, such research can help to detect potential age-

related discrepancies as well as critical periods in the development of working memory in bilingual people.

- Brain Imaging Studies: Employing advanced neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) to investigate the neural mechanisms underlying the relationship between bilingualism, working memory, and cognitive control can yield more concrete results. Researchers can acquire a better understanding of the neurological mechanisms involved in the bilingual advantage in working memory and cognitive control by investigating how bilingualism changes patterns of brain activity and connectivity during working memory tests.

- Social Bilingualism: Investigating the impact of cultural factors on the relationship between bilingualism, working memory, and executive processes may provide an additional dimension for a new understanding. By looking into how cultural background and individual experiences impact the cognitive processes involved in working memory, as well as if there are cultural differences in the cognitive benefits of bilingualism via examining the impact of social bilingualism on key cognitive processes and consequences. Thus, research can give information on how cultural influences interact with bilingualism to alter working memory and cognitive performance.

Conclusion

In conclusion, the present research investigated the impact of bilingualism on working memory abilities. This chapter gave a full review of the previous findings by analyzing the results of the questionnaire used to match the sample, as well as the outcomes of the 2back and Corsi tasks assessing verbal and visuospatial working memory capacity. The study successfully demonstrated a positive link between bilingualism and working memory functions, shedding light on the two's complex processes of identification and discrimination. Furthermore, the chapter provided valuable insights into the research implications while acknowledging the constraints that hampered the investigation. Lastly, we made several recommendations for future research treating similar phenomena.

General Conclusion

General Conclusion

The presented study reflects our modest endeavor to unveil two distinct yet integrated domains within the field of linguistics: bilingualism and working memory. The primary objective was to delve into the effect of utilizing two language systems on the capacity and performance of working memory in individuals who possess the ability to proficiently switch between these two distinct systems. As an attempt to elucidate the existing ambiguity and arrive at a more conclusive understanding, we specifically selected undergraduate participants, namely third-year students from the department of Arabic and English Studies at Yahia Faress University. This decision was made based on the assumption that bilinguals and monolinguals are different in terms of their WM capacities.

This inquiry was submitted in a form of four chapters. In the Initial chapter, we introduced our research by clarifying the main concepts of our study including bilingualism, language proficiency, and working memory. Alongside the main theories that constructed the skeleton of our work. Additionally, we explained the theoretical ground that our research was built upon to provide a clear framework. Association between bilingualism and working memory was established through a connectionist view which brought out the implicit link between the two concepts. Furthermore, it was important to recognize the bilingual advantage hypothesis despite it being inconclusive. Finally, we provided an exhaustive review on the previous studies on bilingualism and working memory for a more comprehensive view on the existing literature on the topic.

In the second chapter of this research, we presented the methodology used to investigate the relationship between bilingualism and working memory performance among Medea University students. We employed a systematic sampling procedure including a preliminary questionnaire and online proficiency test for participant selection. Verbal and visuospatial working memory performances were assessed using the 2back and Corsi tasks, respectively. The Data we obtained were analyzed using SPSS software and ANOVA1. By addressing methodological gaps and employing a structured sampling method, this study aimed to mitigate potential external factors that could impact participants' performance.

The third chapter was dedicated to the analysis of the collected data. Using a variety of research methods, this chapter presented and analyzed the data that had been gathered. The sample was divided into bilingual and monolingual groups using the LSBQ results, and

bilingual participants were further classified as highly proficient and low proficient groups using the EF SET scores. Information about the individuals' language and social backgrounds was revealed through additional LSBQ questions. By using SPSS, mean values and percentages were computed for the numerical data from the 2-back and Corsi tasks. Additionally, One-way ANOVA was utilized in order to compare how well various language groups performed on the working memory tests. In order to gain a deeper understanding of the bilingual experience, regression analyses were used to explore the link between second language use and working memory tasks' performance.

The last chapter provided a discussion of the general findings. The results from the questionnaire and the 2back and Corsi tasks were analyzed, providing a comprehensive discussion of the findings. The study successfully established a connection between the bilingual experience and working memory performance, revealing the intricate relationship between the two. We also highlighted the research implications, acknowledged limitations, and provided suggestions for future research in this area. Overall, this study contributes valuable insights and serves as a foundation for further exploration of the effects of bilingualism on working memory.

This research was a mere attempt to address the methodological shortcomings of similarly conducted studies while investigating the nature of the relationship between bilingualism and working memory. By creating a homogenous sample, we hoped to reach more conclusive results with no interference of external factors. Given that working memory is one of the complex cognitive processes, our aim was to provide a clear route that pinpoints the presumable effects of bilingualism on WM performance. This study also aimed at identifying if there is any observable effect of second language proficiency on working memory performance. Overall, this research has a sole objective of investigating the effects of bilingualism on working memory performance.

Research on the correlation between bilingualism and working memory is significant due to its implications across various domains. It not only helps uncover underlying mechanisms but also explores potential advantages associated with bilingualism. This study goes beyond comparing monolinguals and bilinguals by investigating the influence of second language proficiency on working memory. It assesses identification and discrimination abilities involved in working memory tasks, providing a comprehensive understanding of how language proficiency impacts cognitive processes. By examining verbal and visuospatial working memory capacities using the N-back and Corsi tasks respectively, this study offered

insights into both WM components, contributing to a more holistic understanding of working memory. Indeed; this study sought to advance knowledge in the area of bilingualism and working memory and to increase the validity of conclusions through empirical support and thorough data analysis.

The current study sought to investigate the effect of bilingualism on working memory performance, with a particular emphasis on the identification and discriminating abilities involved in working memory processing. Bilingualism has a good effect on verbal working memory, since it improves both identification and discriminating ability, according to the research. However, there were no substantial impacts of bilingualism on visuospatial working memory. The study also looked into the effects of language proficiency on identification and discrimination abilities in working memory. Surprisingly, the level of linguistic proficiency had no effect on either verbal or visuospatial working memory. In the 2-Back and Corsi tasks, both high and low skilled bilinguals performed similarly, indicating that language proficiency alone does not alter working memory performance. These findings add to the existing body of knowledge by validating the previously proposed hypothesis. They suggest that the mere experience of being bilingual is sufficient to enhance working memory, irrespective of the level of language proficiency.

These findings have important implications for both researchers and practitioners. Educators can use this knowledge to promote bilingual education programs and develop ways that improve learning outcomes for people who are bilingual. The research adds to the development of therapies for cognitive impairments and working memory deficiencies in clinical settings by taking into account the bilingual influence on working memory performance and creating focused rehabilitation programs. Furthermore, this study adds to the continuing discussion over the Bilingual Advantage hypothesis, supporting the idea that bilingualism improves working memory. We acquire a better understanding of the importance of language diversity by investigating the influence of bilingualism on cognitive capacities, which leads to the promotion of bilingualism in societies.

However, it is essential to recognize the study's shortcomings. The research sample was limited to young adults (university students) because other age groups could not be included for more inclusive results; thus, the findings may not be generalizable to other populations. To ensure study generalizability, future studies should involve a broader range of participants from various age groups and language proficiency levels. Furthermore, due to the nature of this study and the constraints of being master's students, a longitudinal study design

was not feasible, restricting the sample size and duration of the study. The use of tasks primarily composed of Latin letters rather than Arabic full word units presented difficulties, as did the lack of access to eye-tracking tools for additional data, concerns about the validity of proficiency tests in an online context, difficulties accessing original sources for the literature review, and a low level of homogeneity among Arabic monolingual participants due to diverse environments and the influence of the French language. Despite these limitations, the study gives useful insights into the bilingualism-working memory relationship, but more research is needed to solve these issues and broaden our understanding of the subject.

To summarize, this thesis adds significantly to our present understanding by demonstrating the positive influence of bilingualism on working memory performance. The data substantially support the assumption that people who are bilingual have cognitive advantages and benefits. This study underlines the need of embracing bilingual education and establishing targeted programs that optimize bilingualism's cognitive potential, resulting in more inclusive and effective learning settings. Future research must delve deeper into the subtle mechanisms underlying the association between bilingualism and cognition, spanning varied populations and studying multiple cognitive domains. By continuing these study efforts, we can gain a better understanding of how bilingualism affects cognition and use this knowledge to maximize human cognitive capacities to the greatest extent possible.

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APPENDICES

Appendix A: The Language and Social Background Questionnaire (LSBQ

YAV Reference ID _____



Lifespan Cognition and Development Laboratory
Ellen Bialystok, Ph.D., Principal Investigator
Department of Psychology, York University

Language and Social Background Questionnaire

Today's Date: _____ (Day Month Year) 1. Sex: Male ☐ Female ☐

2. Occupation/Student Status (i.e. FT/PT, current year of study): _____

3. Handedness: Left ☐ Right ☐ 4. Date of Birth: _____ (Day Month Year)

5. Do you play first-person shooting (FPS)/action video games? **Yes** ☐ **No** ☐
   If **yes**, on average how many hours do you play per week? _____

6. Do you have hearing problems? **Yes** ☐ **No** ☐
   If **yes**, do you wear a hearing aid? **Yes** ☐ **No** ☐

7. Do you have vision problems? **Yes** ☐ **No** ☐
   If **yes**, do you wear glasses or contacts? **Yes** ☐ **No** ☐
   Is your vision corrected to normal with glasses or contacts? **Yes** ☐ **No** ☐

8. Are you colour blind? **Yes** ☐ **No** ☐
   If **yes**, what type? _____

9. Have you ever had a head injury **Yes** ☐ **No** ☐
   If **yes**, please explain: _____

10. Do you have any known neurological impairments? (e.g., epilepsy etc) **Yes** ☐ **No** ☐
    If **yes**, please indicate: _____

11. Are you currently taking any psychoactive medications? **Yes** ☐ **No** ☐
    If **yes**, please indicate: _____

12. Please indicate the highest level of education and occupation for each parent:

Mother		Father	
1. _____	No high school diploma	1. _____	No high school diploma
2. _____	High school diploma	2. _____	High school diploma
3. _____	Some post-secondary education	3. _____	Some post-secondary education
4. _____	Post-secondary degree or diploma	4. _____	Post-secondary degree or diploma
5. _____	Graduate or professional degree	5. _____	Graduate or professional degree
Occupation:	_____	Occupation:	_____
First Language:	_____	First Language:	_____
Second Language:	_____	Second Language:	_____
Other Language:	_____	Other Language:	_____

13. Were you born in Algeria? **Yes** ☐ **No** ☐

If **no**, where were you born? _____

When did you move to Algeria _____

Year

14. Have you ever lived in a place where Arabic is not the dominant communicating language? **Yes** ☐ **No** ☐

		From	**To**
If **yes**, where and for how long?	1. _____	_____	_____
	2. _____	_____	_____
	3. _____	_____	_____
		Year	**Year**

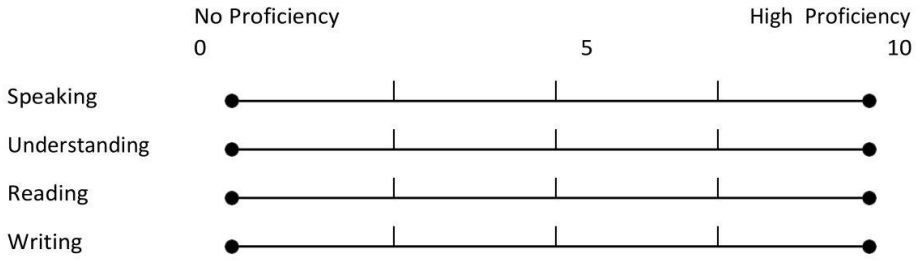
Language Background

15. List all the language and dialects you can speak and understand including Arabic, ***in order of fluency***:

Language	Where did you learn it?	At what age did you learn it? (If learned from birth, write age "0")	Were there any periods in your life when you did not use this language? Indicate duration in months/years.
1._____	☐ **Home** ☐ **School** ☐ **Community** ☐ **Other:** _____		
2._____	☐ **Home** ☐ **School** ☐ **Community** ☐ **Other:** _____		
3._____	☐ **Home** ☐ **School** ☐ **Community** ☐ **Other:** _____		
4._____	☐ **Home** ☐ **School** ☐ **Community** ☐ **Other:** _____		
5._____	☐ **Home** ☐ **School** ☐ **Community** ☐ **Other:** _____		

Relative to a highly proficient speaker's performance, rate your proficiency level on a scale of 0-10 for the following activities conducted in Arabic and your other language(s).

16.1 Arabic



16.2 Of the time you spend engaged in each of the following activities, how much of that time is carried out in Arabic?

	None	Little	Some	Most	All
Speaking	☐	☐	☐	☐	☐
Listening	☐	☐	☐	☐	☐
Reading	☐	☐	☐	☐	☐
Writing	☐	☐	☐	☐	☐

17.1 **Other Language:** _____



17.2 Of the time you spend engaged in each of the following activities, how much of that time is carried out in this language?

	None	Little	Some	Most	All
Speaking	☐	☐	☐	☐	☐
Listening	☐	☐	☐	☐	☐
Reading	☐	☐	☐	☐	☐
Writing	☐	☐	☐	☐	☐

Community Language Use Behavior

18. Please indicate which language(s) you most frequently heard or used in the following life stages, both inside and outside home.

		All Arabic	Mostly Arabic	Half Arabic half other language	Mostly the other language	Only the other language
18.1	Infancy	☐	☐	☐	☐	☐
18.2	Preschool age	☐	☐	☐	☐	☐
18.3	Primary School age	☐	☐	☐	☐	☐
18.4	High school age	☐	☐	☐	☐	☐

19. Please indicate which language(s) you generally use when speaking to the following people.

		All Arabic	Mostly Arabic	Half Arabic half other language	Mostly the other language	Only the other language
19.1	Parents	☐	☐	☐	☐	☐
19.2	Siblings	☐	☐	☐	☐	☐
19.3	Grandparents	☐	☐	☐	☐	☐
19.4	Other Relatives	☐	☐	☐	☐	☐
19.5	Partner	☐	☐	☐	☐	☐
19.6	Roommates	☐	☐	☐	☐	☐
19.7	Neighbours	☐	☐	☐	☐	☐
19.8	Friends	☐	☐	☐	☐	☐

20. Please indicate which language(s) you generally use in the following situations.

		All Arabic	Mostly Arabic	Half Arabic half other language	Mostly the other language	Only the other language
20.1	Home	☐	☐	☐	☐	☐
20.2	School	☐	☐	☐	☐	☐
20.3	Work	☐	☐	☐	☐	☐
20.4	Social activities (e.g. hanging out with friends, movies)	☐	☐	☐	☐	☐
20.5	Religious activities	☐	☐	☐	☐	☐
20.6	Extracurricular activities (e.g. hobbies, sports, volunteering, gaming)	☐	☐	☐	☐	☐
20.7	Shopping/ Restaurants/ Other commercial services	☐	☐	☐	☐	☐
20.8						
20.9	Health care services/ Government/ Public offices/ Banks	☐	☐	☐	☐	☐

21. Please indicate which language(s) you generally use for the following activities.

		All Arabic	Mostly Arabic	Half Arabic half other language	Mostly the other language	Only the other language
21.1	Reading	☐	☐	☐	☐	☐
21.2	Emailing	☐	☐	☐	☐	☐
21.3	Texting	☐	☐	☐	☐	☐
21.4	Social media (e.g. Facebook, Twitter etc.)	☐	☐	☐	☐	☐
21.5	Writing shopping lists, notes, etc.	☐	☐	☐	☐	☐
21.6	Watching TV/ listening to radio	☐	☐	☐	☐	☐
21.7	Watching movies	☐	☐	☐	☐	☐
21.8	Browsing on the Internet	☐	☐	☐	☐	☐

22. Some people switch between the languages they know within a single conversation (i.e. while speaking in one language they may use sentences or words from the other language). This is known as "language-switching". Please indicate how often you engage in language-switching. If you do not know any language(s) other than Arabic, fill in all the questions with 0, as appropriate.

		Never	Rarely	Sometimes	Frequently	Always
22.1	With parents and family	☐	☐	☐	☐	☐
22.2	With friends	☐	☐	☐	☐	☐
22.3	On social media (e.g. Facebook, Twitter)	☐	☐	☐	☐	☐

Thank you for participating!

Appendix B: The EF Standard English Test (EF SET)

EF SET English Score Scale

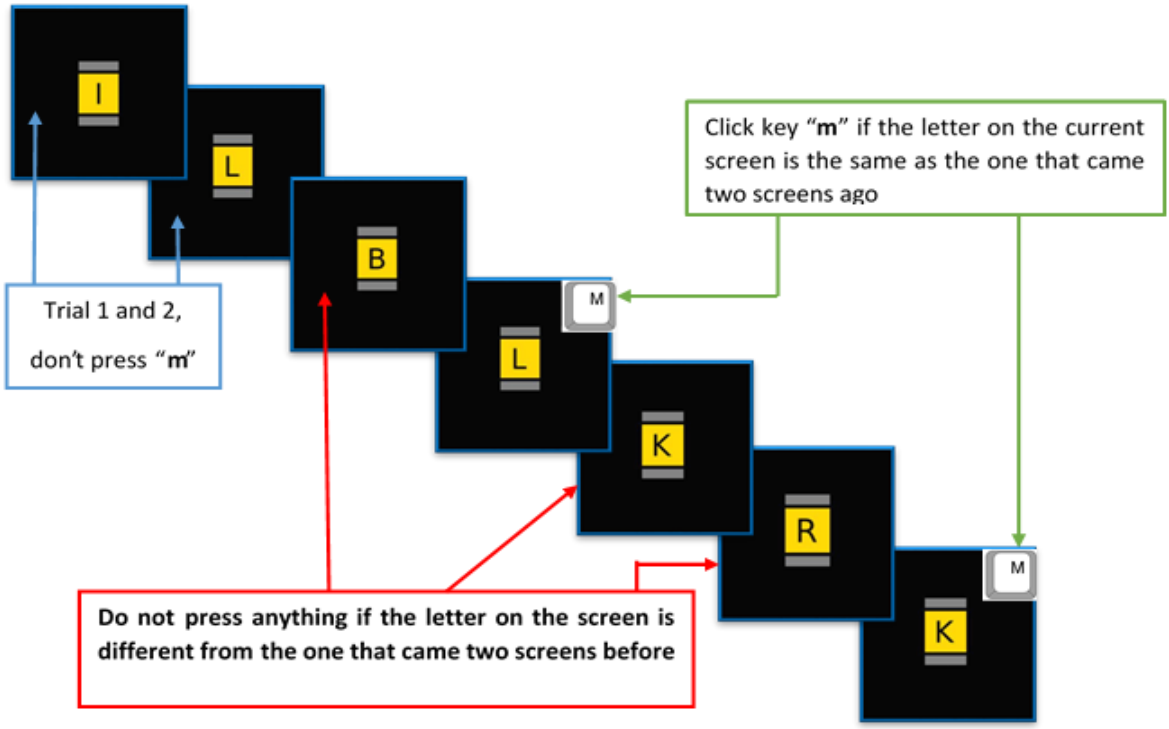
Type of Language User	Level	Code	Description
Basic	Beginner	A1	Understands familiar everyday words, expressions and very basic phrases aimed at the satisfaction of needs of a concrete type
	Elementary	A2	Understands sentences and frequently used expressions (e.g. personal and family information, shopping, local geography, employment)
Independent	Intermediate	B1	Understand the main points of clear, standard input on familiar matters regularly encountered in work, school, leisure, etc.
	Upper intermediate	B2	Understands the main ideas of complex text or speech on both concrete and abstract topics, including technical discussions in his/her field of specialisation
Proficient	Advanced	C1	Understands a wide range of demanding, longer texts, and recognises implicit or nuanced meanings
	Proficient	C2	Understands with ease virtually every form of material read, including abstract or linguistically complex text such as manuals, specialised articles and literary works, and any kind of spoken language, including live broadcasts delivered at native speed

Note. The EF SET is administered as an adaptive test, using a delivery model known as Computer Adaptive Multi-Stage Testing [ca-MST]. This means that as test takers demonstrate their levels of reading and listening comprehension in real time, the test content is adjusted to measure as accurately as possible at the test takers' empirical level of English comprehension

Appendix C: Working Memory Tasks

2-Back Task

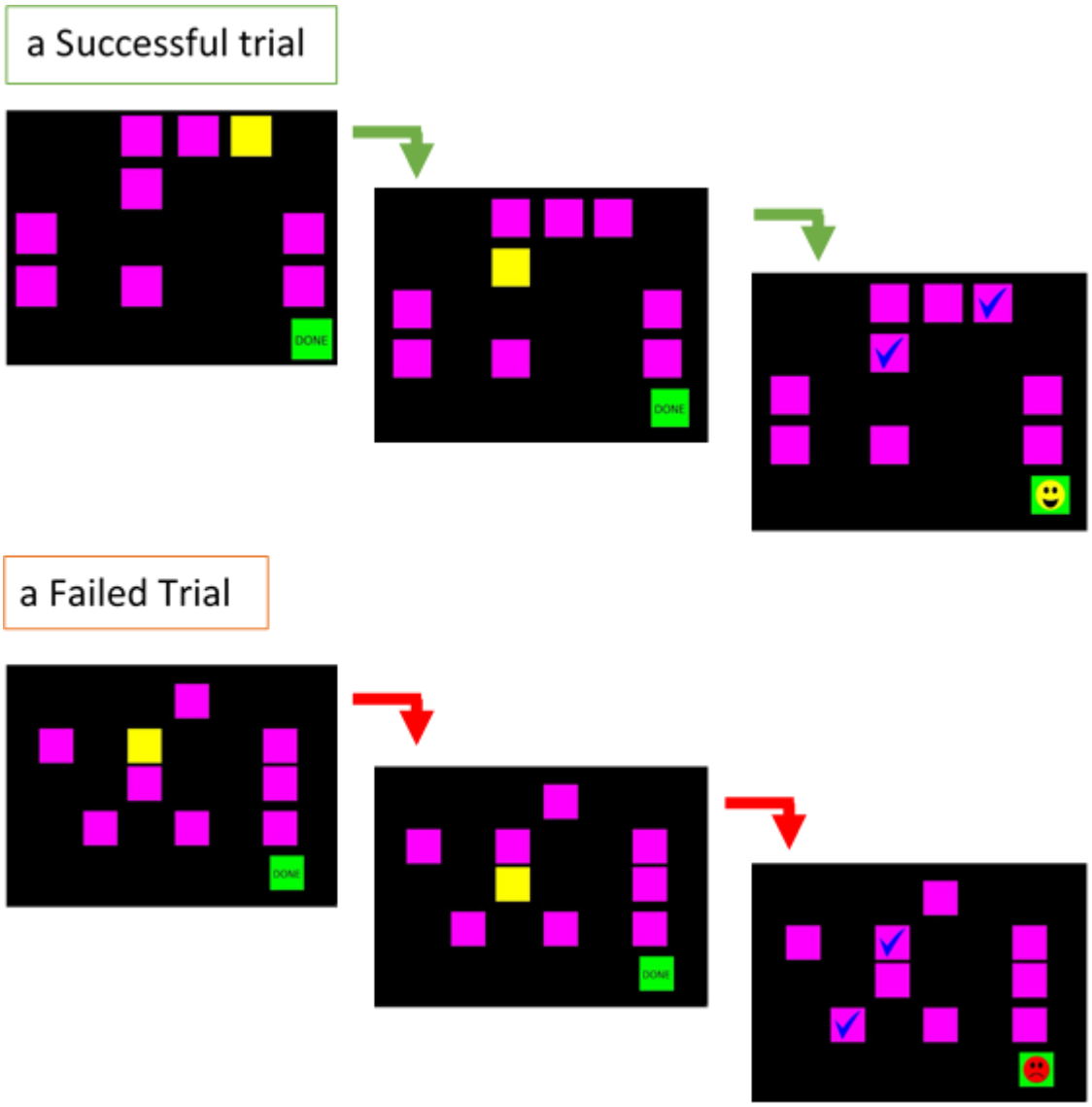
Sequence Demonstration



On a computer monitor, participants are shown a series of Latin letters presented one at a time. Each letter is shown for a 3 seconds. participants must decide whether the number on the screen is the same as one that appeared two steps before in the sequence. If they saw the same letter 2 steps ago, they press the key "m". If they did it correctly, green colors appear around the letter. If they pressed the button when they should not have pressed it, you will see "red" around the letter.

Corsi Task

Sequence Demonstration



On a computer monitor, participants are shown 9 purple blocks and a “done” button. Several of the blocks will turn yellow in a specific order. Once they hear the word “go”, they need to click on on the blocks that were highlighted in yellow in the same order and then click “Done”. It starts with highlighting two blocks, and then one block is added with each trial.

Appendix D: Results of the Language and Social Background Questionnaire (LSBQ) and its association with the WM tasks results

Table

Mean scores for background measures of Bilingual and Monolingual participants.

Background Measures	**Monolingual (n=10)**	**Bilingual (n=10)**
Age	21	21
Gender	5 females	5 females

Figure 1

Relationship between playing video games and accuracy score in 2-back task

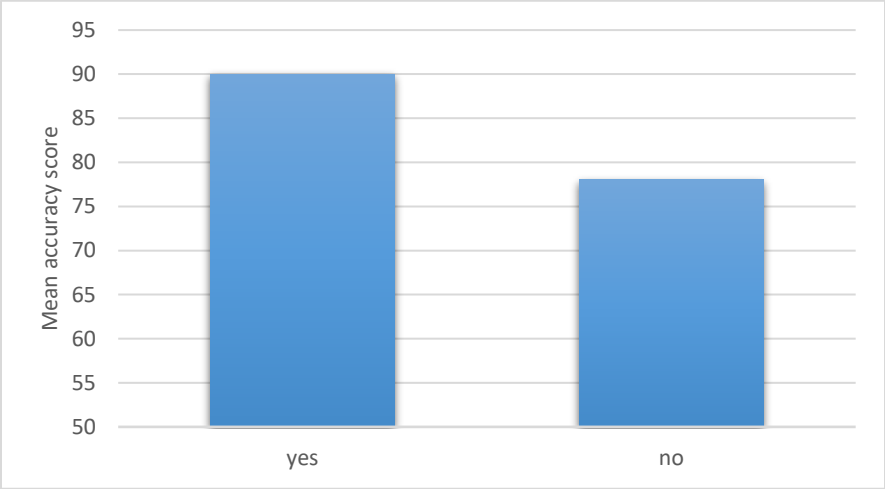
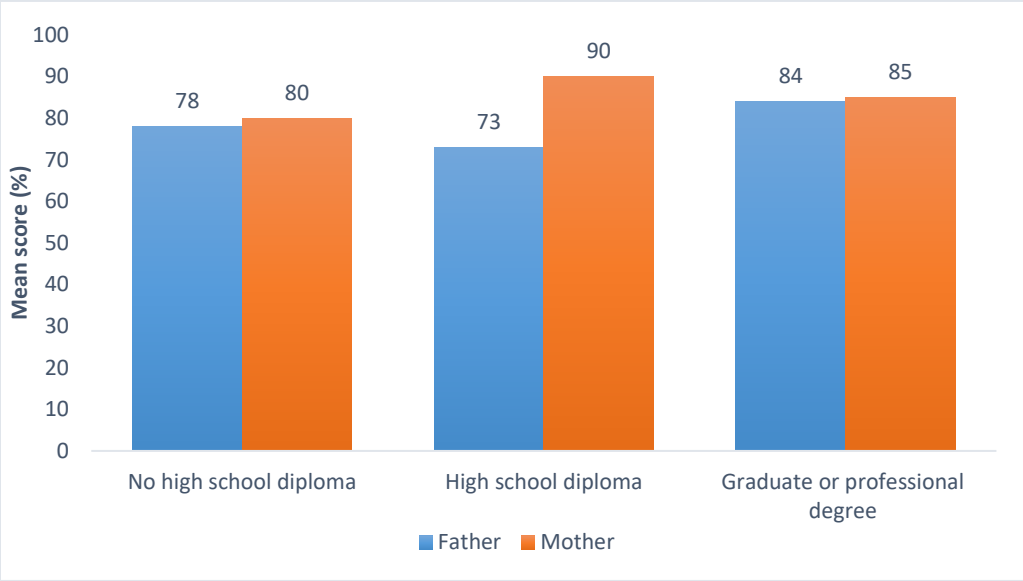


Figure 2



Relationship between participants' Mean 2-back score and their parents level of education

Figure 3.

Relationship between participants' Mean Corsi span and their parents level of education

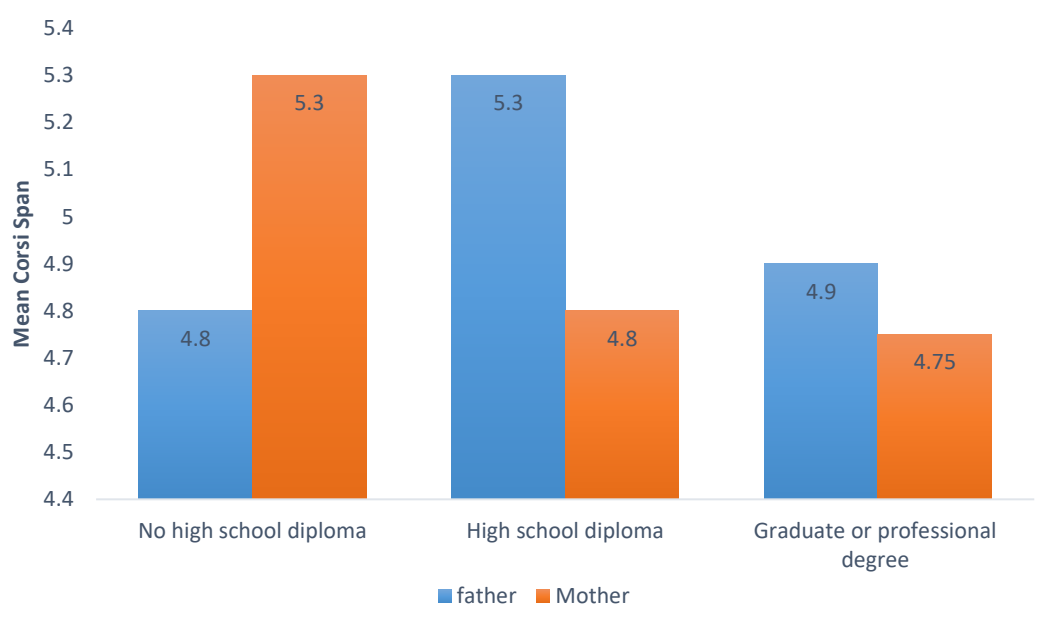


Figure 4:

Relationship between participants' Mean 2-back score and their age of acquisition of L2

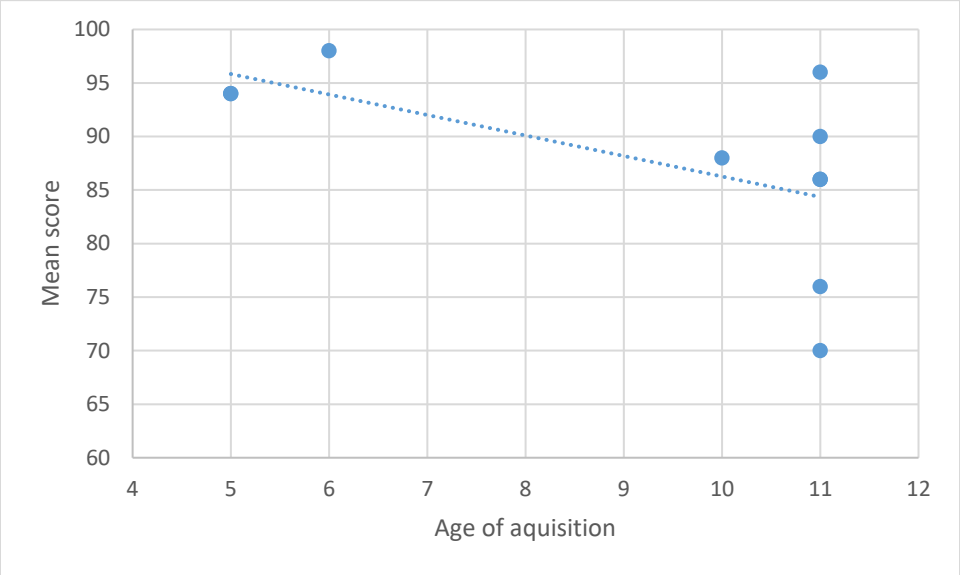


Figure 5:

Relationship between participants' Mean RT and their age of acquisition of L2

