EXPLORING THE RELATIONSHIP BETWEEN BILINGUALISM AND COGNITIVE FLEXIBILITY

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Abstract

Previous literature suggests that bilingual individuals may exhibit enhanced cognitive flexibility due to their frequent monitoring and switching between languages (Ward & Awani, 2024). However, evidence supporting this bilingual advantage remains inconsistent (Paap & Greenberg, 2013). The current study aims to investigate the cognitive advantages associated with bilingualism, particularly focusing on cognitive flexibility as measured by the Trail Making Test (TMT). The study aims to explore whether bilingual individuals experience enhanced cognitive flexibility compared to monolinguals and to examine the roles of the age of second language (L2) acquisition, L2 proficiency, and code-switching frequency in predicting cognitive flexibility scores among bilinguals. This study examined cognitive flexibility in both monolingual and bilingual Cape Breton University students. The results indicated that bilinguals demonstrated significantly greater cognitive flexibility compared to monolinguals. However, no significant correlations were found between cognitive flexibility and the predictor variables of age of acquisition, L2 proficiency, and code-switching frequency. Nonetheless, there were significant correlations among the predictors. All L2 proficiency categories were positively correlated to one another, L2 understanding was negatively correlated to age of acquisition, L2 understanding was positively correlated to code-switching with family, and code-switching with family and friends was positively correlated. These findings support the presence of a bilingual advantage, contributing to the ongoing debate in bilingual literature. However, further research is needed to explore specific linguistic background factors that are predictive of cognitive flexibility.

CHAPTER 1: INTRODUCTION

Research indicates that bilingualism, the ability to speak and understand two languages fluently, can result in enhanced performance on executive function tasks compared to monolinguals. This enhancement is particularly noticeable in tasks that demand a high level of attention and conflict resolution (Bialystok, 2017; Kheder & Kaan, 2021). The bilingual advantage refers to the cognitive benefits gained from managing two language systems, which enhances overall executive functions (Bialystok, 2017). Executive function involves cognitive processes that control our thoughts and actions (Miyake & Friedman, 2012). Such functions are associated with the prefrontal cortex and are critical for complex functions including switching between tasks and inhibiting dominant information (Miyake & Friedman, 2012). The cognitive advantage of bilingualism is attributed to the need for bilinguals to constantly monitor both languages simultaneously, as both languages are always active to some extent (Kheder & Kaan, 2021; Seçer, 2016; Ward & Awani, 2024). This constant activation of language requires bilinguals to use complex cognitive control processes to handle language interference and resolve conflict during language use (Kheder & Kaan, 2021). This active management of two linguistic systems has been linked to cognitive flexibility, the capacity to switch between mental sets in response to changing demands or situations (Seçer, 2016). Researchers have identified specific aspects of the bilingual experience that may contribute to the bilingual advantage. Such as the age at which the second language (L2) was learned, known as age of L2 acquisition (Bonfieni et al., 2019). Another factor important factor is language proficiency, defined as the ability to apply language knowledge for comprehension and production (Bialystok, 2017; Bonfieni et al., 2019; Yow & Li, 2015). Additionally, code-switching, which involves switching between languages within an utterance or conversation is believed to play a significant role (Green & Abutalebi, 2013).

Language and Inhibitory Control

Language control refers to the ability of bilinguals to selectively access the appropriate language during comprehension and production (Bonfieni et al., 2019). It is suggested that the cognitive demand of language control in bilingual speakers is believed to enhance their overall cognitive control skills, which can be beneficial in nonverbal tasks (e.g., Simon Task; Green & Abutalebi, 2013; Kheder & Kaan, 2021). Bilinguals' ability to suppress one language while speaking another is known as active inhibition (Kheder & Kaan, 2021). Conversely, reactive inhibition is defined as the capacity to choose the appropriate language after interference from the irrelevant language. Reactive inhibition is thought to be more effective since it allows the individual to respond appropriately to contradicting language (Kheder & Kaan, 2021). Furthermore, Kheder and Kaan (2021) found that highly proficient bilinguals who frequently switched between their languages had better conflict adaptation and greater accuracy over trials during the Simon task, where participants responded to colored squares by pressing buttons, with the square's location either matching or conflicting with the button associated with its color. This reflects bilinguals' improved inhibition due to their practice in resolving conflicts between their active linguistic systems.

Cognitive Flexibility

A significant amount of research has explored the advantages of bilingualism in cognitive flexibility (Bialystok, 2017; Christoffels et al., 2015; Prior & MacWhinney; 2010; Seçer, 2016). The findings indicate that bilingual individuals exhibit an enhanced ability to switch between multiple tasks, which is believed to result from their frequent practice in alternating between languages and managing linguistic systems (Christoffels et al., 2015; Prior & Macwhinney; 2010; Seçer, 2016). A recent study by Ward and Awani (2024) further supports a bilingual advantage in cognitive flexibility. Their results suggest that bilinguals exhibited better cognitive flexibility in task switching compared to monolinguals in a non-linguistic flexibility task (color-shape task switching paradigm). Similarly, Christoffels et al. (2015) and Prior and Macwhinney (2010) found comparable findings in their study, demonstrating that bilinguals had shorter reaction times on switching tasks compared to monolinguals, which suggests greater cognitive flexibility. Interestingly, a neuroimaging study found bilinguals have greater anterior cingulate cortex influence on the dorsolateral prefrontal cortex and striatum compared to monolinguals while completing a cognitive flexibility task (Becker, 2016). This suggests bilingualism impacts brain structure and neural functioning, showing greater activation during cognitive processes in bilinguals. These findings collectively suggest that bilinguals' ability to manage their two linguistic systems enhances their ability to be cognitively flexible in other nonverbal domains.

The Controversy of The Bilingual Advantage

Although a large portion of background literature supports the bilingual advantage, evidence for this advantage is not always found. For instance, Gosselin and Sabourin (2024) found bilinguals who frequently code-switched between languages had better cognitive flexibility in language-specific cognitive tasks. However, code-switching habits did not predict enhanced cognitive flexibility in domain general tasks (Gosselin & Sabourin, 2024). This suggests that the bilingual advantage may be more pronounced in language-specific contexts, rather than all cognitive contexts.

A study by Costa et al. (2009) explored the conditions that result in a bilingual advantage by comparing reaction times on the flanker task during low monitoring and high monitoring contexts. The low monitoring context contained trials that were majority congruent or incongruent. The high monitoring context consisted of a balance between congruent and incongruent trials. The authors found that monolinguals and bilinguals had very similar reaction times in low monitoring contexts, but the bilingual advantage was present in high monitoring contexts (Costa et al., 2009). Therefore, they did not find a bilingual advantage when the task was less demanding, suggesting that the bilingual advantage is not consistent across all contexts but rather depends on the cognitive demands of the task. Furthermore, the language in which cognitive tasks are performed may influence whether bilinguals experience an advantage over monolinguals (Grundy & Timmer, 2016). For example, Grundy and Timmer (2016) found when bilinguals performed working memory tasks in their first language (L1) they performed better than monolinguals, supporting the bilingual advantage. However, when bilinguals performed the task in their L2, they often performed worse than monolinguals (Grundy & Timmer, 2016). A possible explanation is that bilinguals were more proficient in their L1 compared to their L2, making L1 easier to access and less cognitively demanding. Consequently, when they perform a task in their less proficient language, this may increase the cognitive demand of the task and hinder their performance (Grundy & Timmer, 2016). Therefore, the following studies suggest that the bilingual advantage may vary across different contexts due to the cognitive demands and nature of the task.

Paap and Greenberg (2013) challenge the bilingual advantage as well and claim a bilingual disadvantage. They compared fluent bilinguals to monolinguals with similar demographic factors (i.e., parental education level) using 15 executive processing tests (e.g., Simon, Flanker, Color Shape Switching). Their study found a small bilingual disadvantage on the Simon task; indicating they did not find the expected bilingual advantage in inhibitory control compared to monolinguals (Paap & Greenberg, 2013). This challenges previous claims that bilingualism enhances the ability to suppress conflicting information, reflecting improved inhibition (Kheder & Kaan, 2021). It's possible that bilinguals' ability to inhibit their competing language systems does not translate into non-linguistic tasks, and this active inhibition interferes with performance in other non-verbal domains that require inhibition (Paap & Greenberg, 2013). Overall, past research on bilingualism does not always support the bilingual advantage. This highlights that further research is needed to understand the cognitive processes associated with bilingualism, as well as the factors that may affect whether a bilingual advantage is present.

Code-Switching

Code-switching involves switching between languages within an utterance or conversation (Green & Abutalebi, 2013). Several studies have outlined switching costs which refers to the time and effort it takes to switch from one task to another (Green & Abutalebi, 2013; Kheder & Kaan, 2021; Liu et al., 2016; Liu et al., 2024). A recent study by Liu et al. (2024) highlights that switching between languages involves both inhibitory control to suppress the non-target language, and preparatory control which prepares the speaker for the language task. When this study increased the cued stimulus from 300ms to 800ms they found a reduction in switching costs. Therefore, when bilinguals are given more preparation time before the stimulus is shown, they perform faster than monolinguals. Furthermore, it is suggested by Liu et al. (2016) that cognitive flexibility and frequency of code-switching affect switching costs. Liu et al. (2016) found that bilingual participants who were high in cognitive flexibility had similar switch costs for naming pictures in their L1 and L2. The low cognitive flexibility bilingual participants had greater switching costs when switching back to their L1 after using their L2. It was suggested the differences in switching costs are due to stronger inhibitory control in bilinguals with high cognitive flexibility and weaker inhibitory control in low cognitive flexibility bilinguals (Liu et al., 2016). Similarly, Barbu and Poncelet (2020) found that frequent code-switchers performed better than less frequent code-switchers and monolinguals on a cognitive flexibility task. Furthermore, a study by Beatty-Martínez and Dussias, (2017) suggests that switching costs depends on the bilingual's experience with code-switching. Their study compared non-code-switching bilinguals to frequent code-switching bilinguals. The non-code-switching group lived in Spain and therefore mainly spoke Spanish except for work or school where they would speak English (L2). They compared the less frequent code-switchers to a group of bilinguals who were living in the United States but were raised in Spain, so, they code-switched to English (L2) frequently as it was necessary for daily interactions. The less frequent code-switchers experienced greater switching costs while processing code-switched sentences, whereas the frequent code-switchers did not experience difficulty with the code-switched sentences. Therefore, frequent code-switchers are able to switch between their languages more efficiently compared to less frequent code-switchers. These findings support the idea that language switching habits have a significant impact on the bilingual advantage.

Adaptive Control Hypothesis

Bilinguals adapt their language control processes based on the demands of different interactional contexts, which is supported by Green and Abutalebi's (2013) adaptive control hypothesis. They identified three language-use interactional contexts, such as single language, dual language, and dense code-switching contexts. Single language contexts occur when a speaker primarily uses one of their languages within a specific context without frequent switching between other languages (Green & Abutalebi, 2013). Dual-language contexts are those in which two languages are being used, typically with different speakers, allowing for some switching between languages within the conversation (Green & Abutalebi, 2013). Moreover, in dense code-switching contexts, speakers may switch between their languages within a single phrase or sentence. For example, a French-German bilingual speaker looking to say the word "chose" may use a French verb with a German particle to create a blended word like "choisieren" from the French verb "choisir" and German particle "ieren" instead of switching to the German equivalent "wälen" (Green & Abutalebi, 2013). Further, Green and Abutalebi (2013), state that in dense code-switching environments, the way the speaker uses language works together effectively, allowing the speaker to mix languages as needed to meet their communication goals. For example, speakers may want to use a word from their language not currently being used, so they switch to a word in their other language that accurately conveys their message (Beatty-Martínez & Dussias, 2017). Moreover, Kheder and Kaan (2021) suggest that dense code-switching has the greatest impact on cognitive control processes. In contrast, in single and dual-language contexts, the speaker's language systems compete against each other, making it more difficult for the speaker to stay focused on their goals (Green & Abutalebi, 2013).

Language Proficiency

The role of language proficiency in bilingual individuals is a key factor influencing the bilingual experience. Bonfieni et al. (2019) highlight language proficiency as having a unique role in bilingual language control. They found that greater L2 proficiency was related to faster switching times on a cued language switching task. They also found that greater L2 exposure was related to reduced switching costs. Therefore, greater L2 exposure made it easier to switch between languages because it reduced the dominance of L1 (Bonfieni et al., 2019). Furthermore, Yow and Li (2015) found balanced bilingualism (equal proficiency and usage of both languages) leads to better executive control skills. Specifically, bilinguals who were equally proficient in L1 and L2 had less difficulty switching tasks in a number-letter task and had better performance on the Stroop task. This suggests being equally proficient in both languages could lead to improved cognitive flexibility. Interestingly, Kheder and Kaan (2021) found no correlation between L2 proficiency and the frequency of code-switching. They note that code-switching occurred in varying frequencies independent of proficiency level. They suggest that bilinguals need to have an understanding of both languages to start code-switching, but proficiency and language use seem to be distinct components (Kheder & Kaan, 2021).

A study by Gullifer et al. (2021) emphasizes that language entropy is a significant predictor of L2 proficiency. Language entropy refers to the balance of daily language use between languages. Higher entropy indicates balanced language use of two languages, whereas lower entropy suggests separate use of languages (Gullifer & Titone, 2020). Particularly, Gullifer et al. (2021) found that language entropy in professional contexts was associated with greater L2 proficiency scores. Furthermore, Gullifer and Titone (2020) found entropy scores were the highest and less variable in social and work settings compared to the home context. This suggests bilinguals are more likely to use both of their languages while in social and work settings whereas they are more likely to use one of their languages at home. Moreover, it is found that internal language purposes, such as thinking to oneself or dreaming in L2 are related to greater L2 proficiency. Thus, if bilinguals regularly use their L2 for internal thinking, they become more proficient in that language (Gullifer et al., 2021). An important finding from Gullifer et al. (2021) is that L2 proficiency self-ratings were predictive of objective L2 proficiency scores. That is, bilinguals who performed well on a verbal fluency task also gave themselves a high L2 proficiency self-rating. These findings suggest that subjective L2 measures are effective at capturing objective L2 proficiency. Together, these findings highlight the important role of language use and proficiency in bilingual individuals.

Age of Acquisition

` Research suggests early age of acquisition is a significant factor in the bilingual advantage (Bonfieni et al., 2019; Gullifer et al., 2021 Yow & Li, 2015). Specifically, Bonfieni et al. (2019) suggest early L2 acquisition appears to be more beneficial than later acquisition. They found that earlier acquired languages tend to be more dominant and, therefore easily accessible in language use (Bonfieni et al., 2019). Similarly, Yow and Li (2015) found earlier age of L2 acquisition was positively correlated to performance on the Stroop task. This suggests that those who learned their second language earlier may be able to inhibit irrelevant information more effectively. A different explanation was put forth by Tao et al. (2011) which suggests bilinguals who learn their L2 later in life may have to work harder managing interference from their first language, which results in better performance on conflict resolution tasks. This was demonstrated by comparing early and late bilinguals to monolinguals on a lateralized attention network test (LANT). They found late bilinguals had the fastest reaction time and smallest error rate compared to early bilinguals and monolinguals (Tao et al., 2011). However, the late bilinguals in this sample reported greater proficiency in L1 and equal daily use of both languages compared to early bilinguals who reported primarily using their L2 and had greater proficiency in their L2. Thus, the authors suggest the balance between L1 and L2 proficiency and language use may be more predictive than just age of acquisition alone. On a similar note, Seçer (2016), observed that bilinguals who learned their L2 later still had improved cognitive flexibility compared to monolingual individuals. Further, Seçer (2016) highlights that late bilinguals who achieve higher proficiency levels and frequent usage of L2 can lessen the potential disadvantages of having later L2 acquisition. These findings suggest that both early and late bilinguals have a cognitive advantage compared to monolinguals.

The Current Study

Previous literature on bilingualism suggests that managing two language systems may enhance executive functions, such as cognitive flexibility, due to the need to monitor and switch between languages (Kheder & Kaan, 2021; Seçer, 2016; Ward & Awani, 2024) However, evidence for the bilingual advantage in cognitive flexibility remains inconsistent (Costa et al., 2009; Gosselin & Sabourin, 2024; Grundy & Timmer, 2016; Paap & Greenberg, 2013). These mixed findings highlight the need for further investigation into whether bilinguals exhibit enhanced cognitive flexibility compared to monolinguals. Cognitive flexibility is measured through performance on the Trail Making Test (TMT-B) which assesses the ability to alternate between numbers and letters, thereby reflecting the ability to switch between mental sets. The first research question investigates whether bilinguals exhibit enhanced cognitive flexibility compared to monolinguals. This question is exploratory, given the conflicting results in the literature, and seeks to determine whether an advantage can be detected in a university sample.

Variability in bilingual advantage findings has led researchers to focus on specific bilingual experiences that may influence cognitive flexibility outcomes. Early age of L2 acquisition is linked to better conflict resolution and greater language control (Bonfieni et al., 2019; Yow & Li, 2015). Higher L2 proficiency is associated with faster task-switching and enhanced cognitive flexibility (Bonfieni et al., 2019) Frequent code-switching has been shown to strengthen cognitive control processes, improving performance on tasks requiring inhibition and flexibility (Barbu & Poncelet, 2020; Green & Abutalebi, 2013; Kheder & Kaan, 2021). Despite these findings, no study has simultaneously examined the combined contributions of these three predictors, leaving their relative roles unclear.

The second research question examines the relative contributions of the age of L2 acquisition, L2 proficiency, and code-switching frequency in predicting cognitive flexibility scores in bilinguals. This research is novel because it examines all three predictors in a single model, allowing for a deeper understanding of their unique and combined contributions. By addressing this gap, the current study can provide a greater understanding of how specific bilingual experiences influence cognitive flexibility.

CHAPTER 2: METHOD

Participants

The participants of this study consisted of 53 Cape Breton University (CBU) students over the age of 18 (see Table 1). To encourage participation, a physical poster advertising the study was displayed on bulletin boards throughout campus. The researcher also presented herself during CBU class sessions for a brief oral recruitment presentation. Online recruitment was also conducted through poster advertisements on the CBU Psychology Society's social media platforms (Microsoft Teams, Instagram, Facebook, and X). Exclusion criteria included individuals with neurological impairments, head injuries, and uncorrected vision or hearing impairments. Participants also had to speak English as a first or second language to be eligible to participate in the study. This information was collected using a modified version of the Language and Social Background Questionnaire (LSBQ; see Appendix A). Participants were classified as monolingual or bilingual based on their responses to specific criteria in the modified LSBQ (Anderson et al., 2018).

Group Inclusion

English Monolingual. This group consisted of 17 monolingual CBU students. This included participants who reported using only English in all aspects of their daily lives and had minimal to no proficiency in a second language. Participants who indicated no knowledge of or exposure to a second language were assigned a score of 0 on the proficiency variables. Monolingual group demographics can be found in Table 1. These participants served as a control group.

English Bilinguals. This group consisted of 36 CBU students who had learned English as one of their two languages. The classification as bilingual was based on participants' responses to LSBQ items assessing non-English language proficiency non-English language use at home and non-English language use in social contexts. For instance, in question 16 of the LSBQ, participants were asked to "Please list all the languages and dialects that you can speak and fully understand (including English), in order of fluency." Those who indicated fluency in a language other than English and rated their proficiency for that language in question 18.1, ("Most proficient language other than English (if applicable))," were assigned to the bilingual group. Bilingual group demographics can be found in Table 1. Participants' second language and age of acquisition can be found in Table 2. Further, 22.2% of bilinguals indicated they were multilingual (proficiency in three or more languages). Country of origin varied with 61.1% of participants indicating they were not born in Canada (see Table 3). Further, 76.9% of French speaking students reported acquiring their second language through French immersion in school (see Table 2).

Table 1

Participant Demographic Information.

Group	Mean Age	Gender	N	Program	N
Monolingual	21.1	Male	3	Undergraduate	16
		Female	14	Post-baccalaureate	0
				N/A	1
		Total	17	**Total**	17
Bilingual	23.5	Male	6	Undergraduate	31
		Female	30	Post-baccalaureate	1
		Total	36	N/A	4
				Total	36

Table 2

Bilingual group second language and age of acquisition.

Second Language	N	Average Age Learned	% French Immersion
English	18	6.28	0
French	13	7.77	76.92
Hindi	3	7.67	0
Punjabi	2	11.00	0

Table 3

Bilingual country of origin and first language(s)

Country	Frequency	First Language(s)
Canada	14	English; Mi'kmaq
Germany	2	German
China	3	Chinese; Mandarin
Brazil	1	Portuguese
India	8	Hindi; Punjab
Columbia	2	Spanish
Nigeria	3	Igbo; Yoruba
Mauritius	1	Mauritian Creole
Vietnam	1	Vietnamese
United Arab Emirates	1	Tagalog

Materials

Measures

Modified Language and Social Background Questionnaire. A modified version of the Language and Social Background Questionnaire (LSBQ; Anderson et al., 2018) was used to gather participants' demographic information and language history such as language use, perceived language proficiency, and code-switching frequency. The questionnaire examines language use across various contexts such as with family, friends, and work settings. It also includes questions about code-switching and language use in specific activities like interacting with friends, family, or on social media, providing a detailed understanding of participants' language usage. Modifications were made to the original LSBQ to include more inclusive questions. For instance, the question on gender was changed to an open-ended response question instead of a multiple-choice question. Additionally, the terms "mother" and "father" were changed to "paternal figure 1" and "parental figure 2 (if applicable)" The modifications made were minor, with other questions remaining the same. The questionnaire consisted of 22 open-ended and multiple-choice questions.

Age of L2 acquisition. The first predictor variable, age of L2 acquisition, was derived from Question 16 of the LSBQ, which asks participants to indicate the age at which they began learning their second language. The reported age was recorded as a continuous variable. A value of 0 was used to indicate that language was learned since birth. Monolingual participants were assigned a default code of 999 to indicate that age of L2 acquisition is not applicable.

L2 proficiency. The second predictor variable, L2 proficiency, was calculated as both a composite and individual score based on mean self-report ratings of proficiency in speaking, understanding, reading, and writing the second language (Question 18.1). Participants rated each domain on a scale of 0-10 (0 = *No Proficiency*, 10 = *High Proficiency*). Monolingual participants who report no knowledge of an L2 were assigned a default code of 999 to indicate that L2 proficiency is not applicable.

Code-switching frequency. Code-switching frequency was derived from question 23 of the LSBQ, which measures how often participants switch between languages across various social contexts (e.g., with family, friends, on social media). Participants rate their frequency of code-switching on a 5-point scale ranging from "Never" to "Always," with responses quantified as follows: 1 = *Never*, 2= *Rarely*, 3 = *Sometimes,* 4 = *Frequent*ly 5 = *Always.* Participants received a total score based on their reported code-switching frequency with friends, family, and on social media. Participants also received an individual score for their frequency of code-switching in each social context. Monolingual participants, who lack a second language to switch to, will receive a default value of 999 to indicate that code-switching frequency is not applicable.

Trail Making Test. The Trail Making Test (TMT; Reitan, 1958) is a cognitive task consisting of two parts (TMT-A and TMT-B). Part A of the TMT requires participants to connect circled numbers 1-25 in ascending order as fast as possible without removing their pencil from the page. This task requires visual scanning and sustained attention which serves as a baseline measurement for comparison with part B (Kortte et al., 2002). Part B of the TMT requires participants to connect numbers 1-12 and letters A-L in alternating order (e.g., 1-A-2-B-3-C). This task requires the ability to switch between mental sets by switching between numbers and letters, which is a key factor of cognitive flexibility. Performance on the TMT is assessed based on reaction time to complete each task. If an error occurs when completing the TMT, the researcher will make a note of this to the participant so they can correct their error, this will be included in their reaction time. In the current study, the researcher had to intervene a total of three times, due to two participants selecting the wrong letter, and one participant reversing the correct order of switching. Out of the three participants, two were bilingual and one was monolingual. Kortte et al. (2002) found that TMT-B is closely related to cognitive flexibility which has led to recent studies using the TMT to assess cognitive flexibility (Arbuthnott & Frank, 2000; Bialystok, 2010; Seçer, 2016). Further, Bialystok (2010) observed differences in performance on TMT-A for bilingual children, however, they note that TMT-A is a rather effortless task for most adults, so differences are not expected. Group differences are only expected in part B where cognitive demands are higher, which Seçer (2016) confirmed in their study using TMT-B to measure cognitive flexibility in bilingual adults.

Socioeconomic Status (SES). SES was derived from question 11 of the LSBQ, which assessed participants' SES based on their first listed parental figure's highest level of education attainment (see Table 4). Response options ranged from "No High School Diploma" to "Graduate Degree" with responses quantified as follows: 0 =*No High School Diploma*, 2 = *High School Diploma*, 3 = *Some Postsecondary Education,* 4 = *Post Post Secondary Degree* 5 = *Graduate or Professional Degree.* SES was included as a control variable to account for any socioeconomic differences between monolinguals and bilinguals.

Age. Participants' age was obtained from question 4 of the LSBQ. Age was included as a control variable to ensure there were no significant differences between monolinguals and bilinguals (see Table 1). The groups were compared on age to account for any age-related differences in cognitive ability.

Procedure

Participants were asked to complete the LSBQ, which was administered online via Qualtrics. This format allowed participants to complete the survey at any time and location of their choosing. Before beginning the questionnaire, an informed consent page was presented. This page provided details regarding the nature of the experiment, the researcher's contact details, and the associated risks and benefits of participation. At the end of this consent form, participants could select whether they consented to participate or not. If participants consented to take part in the study, they were asked to provide their email and phone number so the researcher could contact them at a later date for the second part of the study. The second part of the study involved a one-on-one session with the researcher in the Cape Breton University Psychology of Language Lab. Participants who agreed to take part in the section portion of the study were assigned a code based on their language group (e.g., code M for a monolingual, and code B for a bilingual). These codes were used to keep track of participants' responses rather than personally identifiable information to ensure anonymity. The researcher provided participants with a list of available times to complete the lab session. A total of 53 participants completed the lab session, which took approximately 5-10 minutes per person. On the day of the lab appointment, the researcher would greet participants in the Psychology of Language Lab. Once participants were comfortably seated in the lab, the researcher would give a brief overview of the experiment and obtain verbal consent from the participants, confirming their willingness to participate. Then the researcher explained the TMT instructions and provided a brief demonstration of the task. Once the participant confirmed understanding the instructions, the task would begin. Participants began by completing TMT-A, which the researcher would time from start to finish using a stopwatch. Following this they completed TMT-B which the researcher would record from start to finish. If participants made any errors while completing TMT-B the researcher would make note of them and the participant could correct this error. Reaction times for both parts of the task were recorded into a password protected file that corresponded with the participant's survey responses.

CHAPTER 3: RESULTS

LSBQ Survey Data

To determine if the monolingual and bilingual groups differed across socioeconomic status (SES), an independent *t*-test was conducted. The assumption of homogeneity was satisfied via Levene's F test, $F(1, 51) = 0.005$, $p = 0.94$. The results of the *t*-test were non-significant $t(51) = -0.15$, $p = 0.88$, *Cohen's d* = -0.05, suggesting similar levels of SES between the groups. Overall, SES was relatively high with postsecondary and graduate degrees being the most predominant (see Table 4).

To determine whether the monolingual and bilingual groups differed based on age, an independent *t*-test was conducted. The assumption of homogeneity was satisfied via Levene's F test, $F(1, 51) = 0.96$, $p = 0.33$. The results of the *t*-test were non-significant $t(51) = -1.24$, $p = 0.22$, *Cohen's d*=-0.37, suggesting similar age across the groups. The mean age of participants can be found in Table 1.

Table 4

Self-reported education levels for the first listed parental figure.

Group	No High School Diploma	High School Diploma	Some Postsecondary Education	Postsecondary Degree	Graduate Degree
Monolingual	1	4	2	6	4
Bilingual	2	8	5	11	10
Total	**3**	**12**	**7**	**17**	**14**

To examine whether there were any group differences in self-rated English proficiency, independent *t*-tests were conducted assessing English proficiency ratings in, speaking, understanding, reading, and writing. Of the 36 bilingual participants, 22 learned English as a second language and 14 learned English as their first language. Levene's F test for equality of variances was violated for English speaking, $F(1, 51) = 13.20$, $p = 0.01$, so Welch's *t*-test was implemented. The *t*-test for English speaking proficiency revealed a significant difference between the groups, $t(50.99) = 3.17$, $p = 0.003$, *Cohen's d* = 0.82. This indicates that the monolingual group had higher self-reported English speaking proficiency scores. Similarly, for English understanding Levene's F test for equality of variances was violated, $F(1, 51) = 9.21$, $p = 0.004$ so Welch's *t*-test was used. The *t*-test for English understanding revealed a significant difference with monolinguals self-reporting greater English understanding, $t(49.61) = 3.25$, $p = 0.002$, *Cohen's d* = 0.82. In terms of English reading proficiency, Levene's test could not be satisfied, $F(1, 51) = 10.48$, $p = 0.002$. The *t*-test revealed a significant difference between groups, with monolinguals reporting greater reading proficiency $t(50.87) = 2.25$, $p = 0.029$, *Cohen's d* = 0.58. In terms of English writing proficiency, homogeneity of variance was satisfied via Levene's F test, $F(1, 51) = 3.23$, $p = 0.08$. The *t*-test for writing proficiency did not yield a significant result, $t(51) = 1.87$, $p = 0.114$, *Cohen's d* = 0.47, suggesting that both groups reported similar levels of English writing proficiency. The average English proficiency ratings for monolinguals and bilinguals are reported in Table 5.

Table 5

Average self-reported English language proficiency across groups using a 1-10 point scale.

Group	**Speak**	**Understand**	**Write**	**Read**
Monolingual	9.65**	9.77**	9.06	9.35*
Bilingual	8.81	9.06	8.42	8.69

Note. The monolingual group had a significantly higher English speaking, understanding, and reading proficiency score than the bilingual group, **p < 0.01, *p < 0.05.

Next, descriptive statistics were calculated to determine the average self-reported proficiency for bilingual participants' most proficient language other than English. A list of all first languages for the bilingual group is provided in Table 3 and second languages are listed in Table 2. The average self-reported non-English language proficiency is summarized in Table 6.

Table 6

Average self-reported other language proficiency for the bilingual group using a 1-10 point scale.

Group	**Speak**	**Understand**	**Write**	**Read**
Bilingual	7.61	8.25	7.50	7.36

Additionally, descriptive statistics were utilized to determine the frequency of code-switching across different social contexts. The bilingual participants reported varying levels of code-switching ranging from never to always. It was discovered that bilinguals reported code-switching with friends most frequently (see Table 7), followed by code-switching with family members (see Table 8), and code-switching on social media (see Table 9).

Table 7

Frequency of code-switching with friends in bilinguals.

Group	**Code-switching frequency**	**N**
Bilingual	Always	4
	Frequently	7
	Sometimes	11
	Rarely	5
	Never	9

Table 8

Frequency of code-switching with Family Members in bilinguals.

Group	**Code-switching frequency**	**N**
Bilingual	Always	4
	Frequently	3
	Sometimes	10
	Rarely	10
	Never	9

Table 9

Frequency of code-switching on social media in bilinguals.

Group	**Code-switching frequency**	**N**
Bilingual	Always	4
	Frequently	3
	Sometimes	10
	Rarely	10
	Never	9

Cognitive Flexibility: Trail Making Test

A 2(Group) by 2(Test Type) mixed ANOVA was conducted to determine whether bilingual participants demonstrate an advantage in cognitive flexibility compared to monolingual participants. The mean response times and standard deviations across groups for TMT-A and TMT-B are reported in Table 10. The analysis revealed a significant main effect of test type on performance, $F(1, 51) = 117.37$, $p < .001$, therefore, performance differed significantly on TMT-A compared to TMT-B. The analysis also showed a significant main effect of language group, $F(1, 51) = 17.98$, $p < .001$, suggesting reaction times differed based on language group. Additionally, there was a significant interaction between test type and language group $F(1, 51) = 13.65$, $p <. 00$, indicating that the difference in reaction times between TMT-A and TMT-B varied by group. Post hoc comparisons using Tukey's HSD revealed that the bilingual group had significantly faster reaction times on TMT-B compared to monolingual participants (p = < 0.01). However, post hoc comparisons using Tukey’s HSD revealed there were no significant differences between the groups on TMT-A, which was to be expected for this task, ($p = 0.94$).

An analysis of skewness and kurtosis was conducted to assess the normality of the distribution of reaction times for both monolingual and bilingual participants. The monolingual group had a skewness score of z = 2.70, which exceeds the critical threshold of 1.96 for small samples (n < 50; Kim, 2013). The monolingual kurtosis score was z = 1.25, which does not exceed the critical threshold of 1.96. As for the bilingual group, the value for skewness was z = 1.81 and the value for kurtosis was z = 0.59, which are both within the critical threshold.

Due to the skewed distribution monolingual group, three outliers were identified and removed from the sample. A second A 2(Group) by 2(Test Type) mixed ANOVA was conducted and also revealed a significant main effect of test type on performance, $F(1, 48) = 240.51$, $p < .001$, $\eta^2 = 0.59$, indicating that reaction times differed significantly across the tasks. There was also a significant effect of language group on reaction times, $F(1, 48) = 9.361$, $p = 0.004$, $\eta^2 = 0.045$, suggesting reaction times differed based on language group. Additionally, the interaction between language group and test type was significant, $F(1, 48) = 6.19$, $p = 0.02$, $\eta^2 = 0.02$, indicating that the difference in reaction times between TMT-A and TMT-B varied between the groups. Moreover, post hoc comparisons using Tukey's HSD indicated that bilinguals had significantly faster reaction times compared to monolinguals on TMT-B, *(p* = <.001). This indicates that reaction time on TMT-B remained significantly faster for the bilingual group after monolingual outliers were removed. Further, Tukey's HSD revealed the groups did not differ significantly on TMT-A (p = 0.73). Therefore, after removing the monolingual outliers, the group difference remained consistent with the findings from the full sample. The mean response times and standard deviations across groups for TMT-A and TMT-B are reported in Table 11.

Table 10

Means and standard deviations of reaction time on the TMT

Group	**TMT-A**	**SD**	**TMT-B**	**SD**	**N**
Monolingual	24.01	6.80	59.07	25.83	17
Bilingual	22.03	5.39	39.31**	7.90	36

Note. The bilingual group had significantly faster reaction times on TMT-B compared to the monolingual group, $^{**}p < 0.01$.

Table 11

Means and standard deviations of reaction time on the TMT with outliers removed

Group	TMT-A	SD	TMT-B	SD	N
Monolingual	24.37	6.80	48.24	9.44	14
Bilingual	22.03	5.39	39.31**	7.90	36

Note. The bilingual group had significantly faster reaction times on TMT-B compared to the monolingual group after monolingual outliers were removed, $^{**}p < 0.01$

Pearson's Correlations

To explore the relationships between cognitive flexibility and key dimensions of the bilingual experience, including age of acquisition, L2 proficiency, and code-switching frequency, Pearson's correlations were conducted (see Table 12). Specifically, the correlations examined participants' total L2 proficiency which was based on their self-ratings across speaking, reading, writing, and understanding in their L2, and total self-reported code-switching frequency, which was based on their frequency of code-switching with their friends, family, and on social media. The analysis revealed no significant correlations between cognitive flexibility, age of acquisition, total L2 proficiency, and code-switching frequency. However, there was a marginally significant correlation between L2 proficiency and code-switching frequency.

An additional correlation analysis was conducted to examine the relationship between cognitive flexibility, age of acquisition, and subcategories of L2 proficiency and code-switching. This decision is based on the understanding that each subcategory measures distinct aspects of the bilingual experience. Separating proficiency into speaking, understanding, reading, and writing allows for a better examination of how certain language skills relate to cognitive performance. Code-switching was separated into specific contexts such as with friends, family, and on social media because it provides insights into how language use can vary across different social settings. The analysis revealed that the L2 proficiency categories, speaking reading, writing, and understanding all had a significant positive relationship with each other. Furthermore, a significant negative correlation between age of acquisition and L2 understanding was revealed. It was also found that L2 understanding was positively correlated to codeswitching with family. Finally, code-switching with family and code-switching with friends were positively correlated (see Table 13). However, despite breaking down proficiency and code-switching into subcategories, there were still no significant correlations between them and cognitive flexibility.

Table 12

Pearson's correlations among total predictor variables

Variable		RT TMT-B	L2 AOA	L2 Proficiency	Code-switching
1. TMT-B	Pearson's r	—			
	Pearson's p-value	—			
2. L2 AOA	Pearson's r	0.221	—		
	Pearson's p-value	0.195	—		
3. L2 Proficiency	Pearson's r	-0.05	-0.298	—	
	Pearson's p-value	0.773	0.077	—	
4. Code-switching	Pearson's r	-0.05	-0.071	0.313	—
	Pearson's p-value	0.774	0.682	0.063	—

Table 13

Pearson's correlations among predictor variables

Variable		RT TMT-B	AOA Language 2	L2 Speaking	L2 Understanding	L2 Writing	L2 Reading	CS with Family	CS with Friends	CS Social Media
1. RT TMT-B	Pearson's r	—								
	p-value	—								
2. AOA Language 2	Pearson's r	0.221	—							
	p-value	0.195	—							
3. L2 Speaking	Pearson's r	-0.057	-0.197	—						
	p-value	0.742	0.249	—						
4. L2 Understanding	Pearson's r	-0.109	-0.436**	0.655***	—					
	p-value	0.526	0.008	< .001	—					
5. L2 Writing	Pearson's r	-0.015	-0.242	0.541***	0.465**	—				
	p-value	0.931	0.154	< .001	0.004	—				
6. L2 Reading	Pearson's r	-0.013	-0.193	0.688***	0.469**	0.848***	—			
	p-value	0.938	0.26	< .001	0.004	< .001	—			
7. CS with Family	Pearson's r	-0.166	-0.226	0.296	0.467**	-0.062	0.113	—		
	p-value	0.333	0.185	0.08	0.004	0.720	0.511	—		
8. CS with Friends	Pearson's r	-0.097	-0.121	0.302	0.398	0.151	0.356	0.575***	—	
	p-value	0.575	0.484	0.073	0.016	0.381	0.075	< .001	—	
9. CS Social Media	Pearson's r	0.154	0.192	0.309	0.084	0.017	0.154	0.035	0.391	—
	p-value	0.369	0.263	0.067	0.627	0.922	0.371	0.841	0.061	—

Note. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Predictors of Cognitive Flexibility

A multiple linear regression analysis was conducted to investigate whether age of acquisition, total L2 proficiency, and total code-switching frequency serve as predictors of cognitive flexibility in bilingual individuals. These predictors were selected because they represent the overall cumulative dimensions of factors that influence bilingualism. The results indicated that the overall model was not significant, $F(3, 32) = 0.57$, $p = 0.64$, with an R^2 of 0.051. This suggests that the model accounted for only 5.1% of the variance in reaction times on the TMT-B. The adjusted R^2 was -0.038, indicating that the model did not improve upon the mean model. Examining the individual predictors, age of acquisition revealed a non-significant positive relationship with cognitive flexibility, $t(32) = 1.26$, $p = 0.216$. Similarly, code-switching frequency demonstrated a non-significant relationship with cognitive flexibility, $t(32) = -0.24$, $p = 0.81$. Lastly, language proficiency also showed a non-significant relationship with cognitive flexibility, $t(32) = 0.17$, $p = 0.868$.

Another multiple linear regression analysis was conducted to investigate whether specific factors of the bilingual experience predict cognitive flexibility. The analysis was conducted using L2 understanding**,** code-switching with family, and age of acquisition as predictors. These variables were selected based on the results of Pearson's correlations, which revealed significant relationships among these variables. Overall, the regression model was not statistically significant, $F(3, 32) = 0.74$, $p = 0.54$**,** and accounted for only 6.5% of the variance in TMT-B reaction times with an $R^2 = 0.065$ and adjusted $R^2 = –0.023$. Furthermore, L2 understanding revealed a non-significant relationship with cognitive flexibility, $t(32) = 0.23$, $p = 0.81$. Similarly, code-switching with family showed a non-significant relationship, $t(32) = –0.59$, $p = 0.56$. Lastly, Age of acquisition revealed a non-significant relationship with cognitive flexibility, $t(31) = 1.09$, $p = 0.28$. Therefore, revealing that none of the predictor variables were predictive of cognitive flexibility.

CHAPTER 4: DISCUSSION

The first goal of this study was to determine whether bilinguals would display a bilingual advantage compared to monolinguals on cognitive flexibility using the TMT. The results concluded significant differences between the monolingual and bilingual group on TMT-B performance. The bilingual group demonstrated significantly faster reaction times than the monolingual group, suggesting more efficient cognitive flexibility. This finding aligns with previous research suggesting that bilingualism enhances executive functions resulting in faster response times on cognitive tasks (Bialystok, 2017; Christoffels et al., 2015; Costa et al., 2009; Ward & Awani, 2024; Prior & Macwhinney, 2010; Seçer, 2016). Specifically, these findings are consistent with Costa et al. (2009), who noted that bilinguals tend to be faster during cognitive tasks, particularly in high monitoring conditions where they had to continuously adjust to the changing congruent and incongruent trials during the flanker task. This aligns with the cognitive demands of TMT-B, where participants must frequently alternate between numbers and letters, requiring a shift between mental sets. The cognitive demands of TMT-B are greater than those of TMT-A, as participants transition from simply connecting numbers in order, to integrating the switching between numbers and the alphabet. This supports research that suggests the bilingual advantage is prevalent in situations that require greater cognitive resources (Costa et al., 2009). Furthermore, the significantly faster reaction times on TMT-B suggest that bilingual individuals may be better equipped to handle the cognitive demands of TMT-B compared to their monolingual counterparts. This finding supports the notion that bilinguals' ability to manage their two linguistic systems enhances their cognitive flexibility across various domains (Bialystok, 2017; Christoffels et al., 2015; Kheder & Kaan, 2021; Prior & Macwhinney, 2010; Seçer, 2016). Overall, these findings highlight the cognitive advantages associated with bilingualism, particularly in tasks requiring cognitive flexibility.

No significant differences were found in performance on TMT-A between the two language groups. This indicates that bilinguals and monolinguals performed similarly on this less demanding cognitive task. It is noted by Seçer (2016) that TMT-A is a relatively simple task that does not require complex executive functions, therefore group differences would not be expected. Furthermore, Bialystok (2010) emphasizes that the bilingual advantage is context-dependent, indicating that monolinguals and bilinguals can perform similarly on tasks that don't require advanced executive functions such as TMT-A.

Furthermore, SES is known as a factor that can influence cognitive performance, with higher SES generally associated with better performance on cognitive tasks like the backward digit span (i.e., report strings of digits in the reverse order they were presented; Zavala et al., 2018). It's important to note that there were no group differences in SES in the current study, so it is unlikely that socioeconomic factors can explain why the bilingual group was faster on TMT-B. Along with SES, cognitive performance is known to be influenced by age, with some research suggesting peak cognitive abilities in young adulthood (Grundy & Timmer, 2017). However, in this study, the monolingual and bilingual groups were found to have similar mean ages. Therefore, age does not explain the significant difference in cognitive flexibility scores.

The second goal of this study was to investigate the roles of age of L2 acquisition, L2 proficiency, and frequency of code-switching in predicting cognitive flexibility scores among bilinguals. This is based on previous research that identified age of acquisition, L2 proficiency, and code-switching frequency as critical factors influencing the bilingual advantage (Bialystok, 2017; Bonfieni et al., 2019; Green & Abutalebi, 2013 Yow & Li, 2015). However, the current study did not find evidence supporting a correlation or predictive relationship between these bilingual advantage factors and cognitive flexibility. Specifically, the correlation analysis found no significant correlations between cognitive flexibility, age of acquisition, L2 proficiency, or code-switching frequency. However, it is worth noting that the correlation between L2 proficiency and code-switching frequency was marginally significant ($p < 0.06$), suggesting that this relationship may reach significance with a larger sample. Similarly, the multiple linear regression also showed none of the variables were predictive of cognitive flexibility scores. This indicates that the predictor variables did not have a significant relationship with cognitive flexibility.

Despite there being no significant correlations with cognitive flexibility, there were significant correlations among the predictor variables. First, the negative correlation between age of acquisition and L2 understanding suggests that the earlier bilinguals learned their second language, the greater L2 comprehension they reported. This is supported by Rashtchi & Khoii (2024) who note that bilinguals who begin learning a second language at an earlier age tend to have higher proficiency levels. Furthermore, Yow and Li (2015) suggest that early acquisition offers more time for bilinguals to practice using and controlling both languages, which could translate into better understanding over time.

Second, there was a significant correlation between L2 understanding and code-switching with family. This suggests that those who have better L2 comprehension may engage in code-switching more frequently with family members. It is possible that greater L2 understanding increases a bilingual's confidence in using that language, particularly in familiar environments like family settings. When individuals feel they have sufficient comprehension in their L2, they may be more inclined to use it, leading to more frequent code-switching. This aligns with the adaptive control hypothesis proposed by Green and Abutalebi (2013), which suggests that bilinguals adjust their language use based on the context and their comfort level with each language. Additionally, bilinguals likely share similar language backgrounds as their family members, which creates an environment for code-switching. This shared language background allows for communication in both languages, likely enhancing the frequency of code-switching with family.

There was also a significant correlation between code-switching with family and code-switching with friends, suggesting that those who code-switch in friend contexts also reported code-switching with their family. This observation aligns with Dewaele and Li's (2014) findings, who noted that participants who grew up in ethnically diverse environments reported greater code-switching with well-known interlocutors, including friends and family. The authors also highlighted that multilinguals tend to adapt their language use based on the interlocutor type, with the highest frequency of code-switching occurring in interactions with friends (Dewaele & Li, 2014). Interestingly, participants in the current study reported code-switching most frequently with friends. This pattern may be attributed to CBUs multicultural campus, where the diversity among students creates an environment that encourages interactions with peers who have similar language backgrounds, leading to switching between their languages more often with friends.

Despite the interesting correlations among the predictor variables, none of these factors were predictive of cognitive flexibility. One possible explanation for this is that the TMT-B may not have been cognitively challenging enough for bilinguals, who demonstrated consistently fast performance. As Costa et al. (2009) suggest, bilingual advantages in executive control typically arise under high demand conditions requiring greater cognitive resources. Therefore, it is possible the TMT was too easy for bilingual participants, resulting in little variability in responses. To address this issue and potentially reveal a significant relationship between predictor variables and cognitive flexibility, future research should use a more challenging cognitive flexibility task. It's possible a task such as a task-switching paradigm similar to the one used by Ward and Awani (2024) would be a greater challenge for bilinguals, thus tapping into their higher cognitive resources. The task-switching paradigm used by Ward and Awani (2024) involved participants categorizing stimuli by either colour (red or blue) or shape (horse or cow) based on a preceding cue. The task included pure blocks where participants responded to only one feature and a switch block where they switched between categorizing by colour or shape. Ward and Awani (2024) found that bilinguals exhibited better cognitive flexibility in this task, specifically showing a reduced switch cost compared to monolinguals. By using this more demanding task-switching paradigm, future research may be able to increase the cognitive demand and generate greater variability in performance among bilinguals. This could potentially offer insights into whether age of acquisition, L2 proficiency and code-switching frequency predict enhanced cognitive flexibility.

Overall, code-switching frequency was relatively low with family, friends, and on social media, a pattern may be attributed to the mixed sample of bilingual participants. Of the 36 bilingual participants, 14 reported learning English as their first language (L1), while the remaining 22 acquired English as their L2. The 14 English L1 speakers may reveal more consistent English language use and be less likely to code-switch due to Cape Breton being a predominantly English speaking area. Additionally, among the 13 French bilinguals, 10 reported learning French as a second language through a school French immersion program, with most of their French use limited to school settings. Notably, 9 of these French L2 speakers indicated that they use “all English” in various social contexts such as home, work, and hobbies, likely due to limited opportunities to use French since graduating from high school. This highlights the low usage of L2 among most French L2 bilinguals due to fewer opportunities to use French in Cape Breton.

Furthermore, the 22 participants who learned English as a second language likely have limited opportunities to engage in code-switching, as English is the language of instruction at CBU and the dominant language in Cape Breton. This limited exposure to settings that naturally encourage code-switching may contribute to the overall low frequency of code-switching reported. Consequently, this may also help explain the weak correlations between code-switching and cognitive flexibility. For example, a native Chinese speaker living in Cape Breton may have limited opportunities to code-switch unless interacting with another native Chinese speaker. Furthermore, a study by Beatty-

Martinez & Dussias (2017) examined two separated groups of bilinguals based on their code-switching frequency. The first group did not code-switch often as they were living in an area that predominately spoke their first language (Spanish). The second group consisted of frequent code-switchers who were native Spanish speakers currently living in the United States (mostly English speaking country). They used event related potentials to measure the processing of code-switched sentences. They found that the group that frequently code-switched did not show difficulty processing these sentences, but the group that did not frequently code-switch had difficulty processing. This suggests that the frequent code-switchers had more efficient language processing than the less frequent code-switchers. If the current study had included more individuals from bilingual communities with a high frequency of code-switching, similar to the code switchers in the Beatty-Martínez & Dussias (2017) study, there may have been a significant relationship between code-switching and cognitive flexibility. These findings highlight how the language environment plays a role in influencing code-switching habits. It also suggests that code-switching may play a more important role in cognitive flexibility if it occurs more frequently.

Furthermore, the current study utilized subjective self-ratings to assess L2 proficiency, which aligns with previous research by Gullifer et al. (2021), who found that self-rated L2 proficiency was predictive of objective proficiency scores. However, it’s important to consider that objective measures of L2 proficiency may be a stronger predictor of cognitive flexibility. Hulstijn (2012) supports this idea, stating that objective language tests provide a more accurate assessment of language proficiency, which is critical for understanding bilingual performance. Supporting this, Olson (2024) suggests combining self-ratings with standardized tests may provide a more comprehensive view of language proficiency. They note that while both tests can be beneficial, using multiple assessment methods is suggested for a greater understanding of language proficiency (Olson, 2024). Similarly, research by Aubin (2018) highlighted the limitations of subjective ratings by showing weak correlations between self-rated proficiency and objective scores on the Nelson-Denny Reading Test, suggesting that self-assessments may not fully capture actual language comprehension and vocabulary skills. Furthermore, findings by Gehebe (2023) reveal that bilinguals with high L2 exposure had more consistent performance across subjective and objective language proficiency measures. This is demonstrated by a strong correlation between their subjective and objective proficiency scores. However, bilinguals who had low L2 language exposure had weak correlations between their subjective and objective language proficiency in reading and speaking. These results suggest that the relationship between objective and subjective proficiency measures is much stronger among bilinguals who are highly exposed to their L2 compared to those who have limited exposure. This finding implies that the accuracy of self-ratings may depend on an individual's exposure to the language. The current study consisted of a mixed group of bilinguals with varying levels of L2 exposure. It is possible that relying on their subjective proficiency scores may have not fully captured their L2 proficiency and perhaps objective language proficiency is a better predictor of cognitive flexibility. Therefore, incorporating objective assessments, such as standardized language tests, could provide a more accurate and consistent measurement of L2 proficiency across participants with varying levels of exposure. Consequently, future research should consider utilizing a mixed-methods approach that combines both subjective and objective assessments to better understand the complex relationship between language proficiency and cognitive flexibility in bilingual individuals.

On a final note, the insignificant results also may be influenced by the low sample size in the bilingual group, which likely reduced the statistical power of the correlation and regression analyses. Future studies would benefit from obtaining a larger sample size since this may provide more power to detect whether linguistic background variables are predictive of cognitive flexibility.

In conclusion, the current study supports the notion of a bilingual advantage. The findings revealed that bilingual participants demonstrated significantly faster reaction times on TMT-B compared to monolingual individuals, indicating a bilingual advantage in cognitive flexibility. This aligns with previous research that suggests managing two language systems may enhance executive functions, particularly in tasks requiring higher cognitive demands (Kheder & Kaan, 2021; Seçer, 2016; Ward & Awani, 2024). Furthermore, the study examined the combined contributions of age of acquisition, L2 proficiency, and code-switching frequency in predicting cognitive flexibility. Although the study found no significant correlations between cognitive flexibility and the predictor variables of age of acquisition, L2 proficiency, and code-switching frequency, there were significant correlations among predictor variables. It is suggested that earlier age of acquisition is associated with better L2 comprehension. It is also suggested that individuals with better L2 comprehension are more likely to engage in code-switching with their family and those who frequently switch languages with family members also tend to do so with friends. Overall, the study indicates that while bilingualism may promote cognitive advantages, the specific factors influencing cognitive flexibility require further research. Future studies should utilize a more challenging cognitive flexibility task, objective language proficiency measures, and bilinguals with greater L2 exposure to gain a better understanding of the factors that influence the bilingual advantage.

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Appendix A
Modified Version of the Language Social Background Questionnaire
(LSBQ; Anderson, Mack, Keyvani Chahi. & Bialystok, 2018)

1. Gender: ____
2. Program and year of study (if applicable):
____
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 any 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. Please indicate the highest level of education and occupation for current parental figure(s):

Parental Figure 1 [ ] No High School Diploma [ ] High School Diploma [ ] Some postsecondary education [ ] Postsecondary degree/diploma [ ] Graduate or Professional Degree Occupation: ______________________ First Language: ____________________ Second Language: __________________	Parental Figure 2 (if applicable) [ ] No High School Diploma [ ] High School Diploma [ ] Some postsecondary education [ ] Postsecondary degree/diploma [ ] Graduate or Professional Degree Occupation: ______________________ First Language: ____________________

Other Language(s): ________________	Second Language: ________________
	Other Language(s): ________________

12. Were you born in Canada: [ ] Yes [ ] No
    If no, where were you born? ___________________________________
    When did you move to Canada (Year)? ___________________________
13. Have you ever lived in a place where English is not the dominant communicating language?
    [ ] Yes [ ] No
    If yes, where and for how long?

Place	From (Year)	To (Year)
1.		
2.		
3.		

14. If you lived in Canada for most of your life, were you ever enrolled in the French immersion
    program? [ ] Yes [ ] No
    If yes, at what grade levels (please check all that apply)?
    [ ] Elementary (Primary to Grade 6)
    [ ] Junior High (Grades 7-9)
    [ ] High School (Grades 10-12)
15. If you were enrolled in the French immersion program, did you stay enrolled throughout the duration of the program (e.g., did not switch to the English program from Grades 7-9)?
    [ ] Yes [ ] No [ ] Not applicable

If no, please indicate which grade level you switched out of the program:
____

Language Background

16. Please list all the languages and dialects that you can speak and fully understand (including English), in order of fluency (first spoken language, second spoken language, etc.):

Language	Where did you learn it? (Please check all that apply)	At what age did you learn it? (if learned from birth write age "0")	Were there any periods in your life where 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 English and your other language(s).

17.1 **English**

	No Proficiency									High Proficiency
Speaking	0	1	2	3	4	5	6	7	8	9	10
Understanding	0	1	2	3	4	5	6	7	8	9	10
Writing	0	1	2	3	4	5	6	7	8	9	10
Reading	0	1	2	3	4	5	6	7	8	9	10

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

	None	Little	Some	Most	All
Speaking	[ ]	[ ]	[ ]	[ ]	[ ]
Listening	[ ]	[ ]	[ ]	[ ]	[ ]
Reading	[ ]	[ ]	[ ]	[ ]	[ ]
Writing	[ ]	[ ]	[ ]	[ ]	[ ]

18.1 Most proficient language other than English (if applicable): ________________________

	No Proficiency									High Proficiency
Speaking	0	1	2	3	4	5	6	7	8	9	10
Understanding	0	1	2	3	4	5	6	7	8	9	10
Writing	0	1	2	3	4	5	6	7	8	9	10
Reading	0	1	2	3	4	5	6	7	8	9	10

18.2 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	[ ]	[ ]	[ ]	[ ]	[ ]

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

	All English	Mostly English	Half English half other language	Mostly the other language	Only the other language
Infancy	[ ]	[ ]	[ ]	[ ]	[ ]
Preschool age	[ ]	[ ]	[ ]	[ ]	[ ]
Primary School Age	[ ]	[ ]	[ ]	[ ]	[ ]
High School Age	[ ]	[ ]	[ ]	[ ]	[ ]

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

	All English	Mostly English	Half English half other language	Mostly the other language	Only the other language
Parental Figure(s)	[ ]	[ ]	[ ]	[ ]	[ ]
Other Relatives	[ ]	[ ]	[ ]	[ ]	[ ]
Partner	[ ]	[ ]	[ ]	[ ]	[ ]
Roommate(s)	[ ]	[ ]	[ ]	[ ]	[ ]
Neighbours	[ ]	[ ]	[ ]	[ ]	[ ]
Friends	[ ]	[ ]	[ ]	[ ]	[ ]

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

	All English	Mostly English	Half English half other language	Mostly the other language	Only the other language
Home	[ ]	[ ]	[ ]	[ ]	[ ]
School	[ ]	[ ]	[ ]	[ ]	[ ]
Work	[ ]	[ ]	[ ]	[ ]	[ ]
Social activities (e.g., at the movies)	[ ]	[ ]	[ ]	[ ]	[ ]
Extracurricular activities (e.g., hobbies, sports, volunteering)	[ ]	[ ]	[ ]	[ ]	[ ]
Shopping/Restaurants/ other commercial services	[ ]	[ ]	[ ]	[ ]	[ ]
Health care services/ Government/ Banks	[ ]	[ ]	[ ]	[ ]	[ ]

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

	All English	Mostly English	Half English half other language	Mostly the other language	Only the other language
Reading	[ ]	[ ]	[ ]	[ ]	[ ]
Emailing	[ ]	[ ]	[ ]	[ ]	[ ]
Texting	[ ]	[ ]	[ ]	[ ]	[ ]
Social Media (Instagram, Tiktok, etc.)	[ ]	[ ]	[ ]	[ ]	[ ]

Writing shopping lists, notes, etc.	[ ]	[ ]	[ ]	[ ]	[ ]
Watching TV/ listening to the radio	[ ]	[ ]	[ ]	[ ]	[ ]
Browsing the internet	[ ]	[ ]	[ ]	[ ]	[ ]

23. 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 English, please leave this section blank.

	Never	Rarely	Sometimes	Frequently	Always
With Family Members	[ ]	[ ]	[ ]	[ ]	[ ]
With Friends	[ ]	[ ]	[ ]	[ ]	[ ]
On Social Media (Instagram, Tiktok, etc.)	[ ]	[ ]	[ ]	[ ]	[ ]

Thank you for participating!

Appendix B

Trail Making Test (TMT) Part A and B

Instructions:

Both parts of the Trail Making Test consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1 – 25, and the patient should draw lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1 – 12) and letters (A – L); as in Part A, the patient draws lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). The patient should be instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. Time the patient as he or she connects the "trail." If the patient makes an error, point it out immediately and allow the patient to correct it. Errors affect the patient's score only in that the correction of errors is included in the completion time for the task. It is unnecessary to continue the test if the patient has not completed both parts after five minutes have elapsed.

Step 1: Give the patient a copy of the Trail Making Test Part A worksheet and a pen or pencil.

Step 2: Demonstrate the test to the patient using the sample sheet (Trail Making Part A – *SAMPLE*).

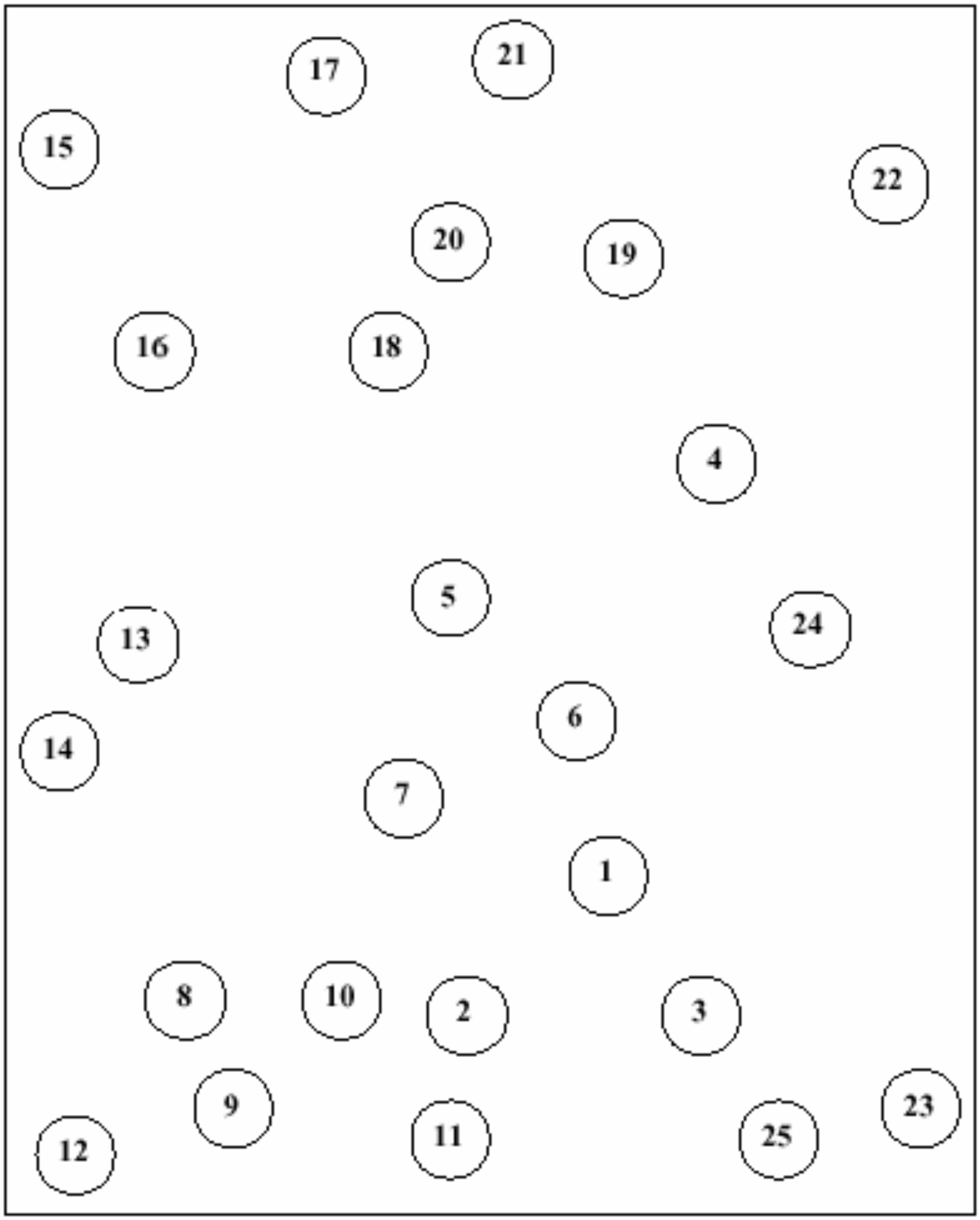
Step 3: Time the patient as he or she follows the “trail” made by the numbers on the test.

Step 4: Record the time.

Step 5: Repeat the procedure for Trail Making Test Part B.

Trail Making Test Part A

Participant's code: ____________________________Date:________________________



Trail Making Test Part B

Participants code: __________________________Date:_______________________