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Multilingual Experience and Executive Functions among Children and Adolescents in a Multilingual City

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Abstract

Children develop their language capacities and executive functions (EF) throughout their school-aged years. Research has shown that bilingual children show different patterns of EF performance when compared to their monolingual counterparts. However, it is less clear how variations in children's bilingual experiences associate with variation in EF performance. The current study examined the variability of multilingual experience across the contexts of home and school and how it relates to EF. Sixty-seven children and adolescents from a multilingual community completed EF tasks that assessed their attention and monitoring. Given the sociolinguistic landscape of a multilingual community, all participants reported having exposure to at least a second language, and their multilingual experience was examined on a continuum across different contexts. Age was positively associated with both attention and monitoring. In addition, the degree of dynamic multilingual experience contributed to performance on monitoring. Our study shows that in children and adolescents, multilingual experience across the contexts of home and school accounted for additional variation in EF beyond chronological age.

Keywords: Multilingualism, bilingualism, executive functions, children and adolescents, contextual factors, multilingual community, sociolinguistic factors

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1. Introduction

Executive Functions (EF) is an umbrella term comprising multiple cognitive processes that underlie goal-directed behavior and develop in parallel with the maturation of the prefrontal cortex (Best & Miller, 2010). Research has demonstrated malleable associations between EF and different life experiences at different periods of development, including parent–child attachment security (Bernier et al. 2015), music training (Moreno et al. 2011), socioeconomic status (Hackman et al. 2015), and video-gaming experience (Bavelier et al. 2012). Bilingualism is one such experience that has been studied. In some studies, bilingual children demonstrated faster response times or higher accuracy on tasks that require inhibitory control, attentional control, and cognitive flexibility (see review in Bialystok and Craik 2022). These findings have been documented even when language combinations (Barac and Bialystok 2012) and socioeconomic factors are considered (Calvo and Bialystok 2014).

Simultaneously, there is also a significant body of research demonstrating limited or no relationship between bilingualism and EF in children (Antón et al. 2014; Gathercole et al. 2014). These equivocal findings can at least in part be explained by the wide variety of EF tasks, and the adoption of between-group designs comparing EF between monolingual and bilingual groups with a variety of labels and descriptions (Surrain and Luk 2019). In fact, there has been an increasing concern regarding between-group investigations because a categorical nature of bilingualism is implicitly assumed (Whitford and Luk 2019, but see an innovative solution in Kremin and Byers-Heinlein 2021). In reality, bilingualism is best defined as a dynamic experience that depends on our day-to-day interaction within specific contexts comprised of the

meso (e.g. home, school, work) and macro (e.g. community or country) levels of the social environment (Grosjean 2013). In the current paper, we opt to use the term *multilingual* to illustrate the dynamic language exposure and usage experienced by the participants in our study. However, we maintain the use of the term *bilingual* to reflect the description of the literature.

Researchers have recently advocated for studies to adopt multi-factorial, individual differences approach (e.g. Takahesu Tabori, Mech, and Atagi 2018) and embrace variability by examining individual differences in multilingual experiences to better understand the cognitive consequences of bilingualism. Emerging studies have examined bilingualism as a continuous, rather than categorical, variable in children (e.g. Chung-Fat-Yim et al. 2020; Guerrero et al. 2016; Thomas-Sunesson, Hakuta and Bialystok 2018). Here, we adopted a multidimensional and continuous approach to examine age-related changes in EF among multilingual children living in a multilingual community. The focus of the current study was to examine potential sources of variation in multilingual experiences that may modulate EF development beyond chronological age in a cross-sectional sample.

2. Literature review

One recent theoretical framework posed to describe bilingual management is the Adaptive Control Hypothesis (ACH, Green and Abutalebi 2013), which posits that individuals adapt to the language demands in their social environment, which in turn shapes cognitive processes in general. ACH accounts for bilingual experience from different interactional contexts, which are hypothesized to require different degrees of language control. Green and Abutalebi (2013) defined three interactional contexts that involve language control processes: single-language, dense code-switching, and dual-language. A single-language bilingual context is exemplified by an individual speaking English at home and French at work, resulting in a clear separation between the contexts

in which each language is used. A dense code-switching context is exemplified by an individual freely speaking both languages to other speakers in which multiple languages are used within the same utterances. The speaker in this context uses either language spontaneously, sometimes switching languages within a sentence and thus engaging in minimal language control processes.

The dual-language context is the most demanding interactional context, occurring when a speaker communicates in two languages within a single context (e.g. a bilingual child speaking English to an English teacher, and speaking French to a French teacher at school). Bilinguals speaking in a dual-language context engage in more challenging language control processes since they have two competing language systems between which they must select, switch, and continuously manage. Similarly, control processes involved in nonverbal tasks require the monitoring of context, maintaining the action goal, and resisting interference from other competing actions that may be triggered by the situational context. Hence, the dual-language context is the most cognitively demanding with the continuous cognitive control demands, which is conjectured to potentially reveal in EF-related behavioral performance. One important note is that the three contexts described in ACH were acknowledged to be overlapping in some contexts and not entirely categorical in nature. Since the ACH accounts for the dynamic experience of bilingual interaction, this framework could potentially shed light on the diverse findings in the relationship between bilingualism and EF in development. Understandably, children's everyday language experience in meaningful social contexts will play an important role in shaping their cognition.

An open question is how EF develops across childhood and adolescence and how life experiences, such as bilingualism, modulate EF in development. The broad definition of EF and the wide variety of tasks used to assess EF have resulted in theoretical and methodological challenges to extract a clear developmental trajectory of EF (Best and Miller 2010), which may

in part also contribute to the inconsistent findings regarding how EF and bilingualism are related. In the adult literature, EF research has relied on Miyake and colleagues' seminal work (2000) defining three interrelated yet distinct components of EF; inhibitory control, working memory, and cognitive flexibility. This framework, however, was derived from studies with young adults and therefore, it is unclear whether these components of EF are applicable to developing samples. Furthermore, Bialystok and Craik (2022) have elaborated the cognitive demand associated with utilizing multiple languages as a consequence for attention in general, rather than specific component skills in EF.

Huizinga and colleagues (2006) examined the developmental trajectory of EF across four age groups (ages 7, 11, 15, and 21) using nine EF tasks tapping into the three components of EF defined by Miyake et al. (2002). The results revealed developmental differences across the three foundational components with cognitive flexibility defined by a developmental trajectory extending to adolescence and working memory extending into young adulthood. In another study, age-related EF improvements were also observed across the Stroop task, Digit Span, Iowa Gambling Task and the Delay Discounting tasks (Prencipe et al. 2011). In sum, such findings suggest the importance of assessing EF using multiple tasks across childhood and adolescence.

Regarding the issue of EF tasks, Best and Miller (2010) outlined the matter of 'task impurity' whereby studies often define the performance on a complex EF as reflective of the participant's ability on a singular cognitive construct among many others that are involved in successful task completion. In addition, the cognitive constructs assessed are often operationally defined differently across studies using the same task. For example, the Wisconsin Card Sorting Test (WCST; Berg 1948) has been classified as an 'inhibition' task by some authors (Rennie et al. 2004), and a 'cognitive flexibility' tasks by others (Garon et al. 2008). When examining the

interplay between EF and bilingualism, it is therefore important to consider developmental differences when assessing EF processes and use EF tasks that tap into several EF components, so that relations can be further examined.

Recent studies with bilingual children have revealed that attention plays an important role in bilingualism and EF (Chung-Fat-Yim et al. 2020). When attention and EF were examined in bilingual children, a higher degree of bilingualism and attention were both associated with better performance on EF tasks of inhibition and interference control (Sorge et al. 2016). In a similar study with 8- to 10-year-olds attending a bilingual school, both bilingualism and attention had a continuous influence on their EF performance as measured by the flanker task (Chung-Fat-Yim et al. 2020). These findings demonstrate that variations in bilingual children's attention are related to EF performance and suggest the importance of examining attention, in addition to more complex characteristics of EF, when studying the relationship between bilingualism and EF.

To measure attention in the EF framework, the Dimension Card Sorting (DCCS, Zelazo 2006) and the WCST (Berg 1948) have been used extensively with preschoolers, children, and adolescents (Ross and Melinger 2017). In WCST, participants are asked to sort cards according to three different sorting rules. However, they are not told about the rule in which they can sort the card and must rely on the feedback they receive for each sort on whether it is correct or not. To successfully complete the task, the participant must hold the acquired rule in their mind (i.e. working memory), suppress irrelevant cues or responses (i.e. inhibitory control), shift flexibly between rules (i.e. cognitive flexibility), while monitoring their performance from feedback. Given that the WCST is a complex task that involves multiple components of EF based on earlier models, performance in this task also reflects abilities to coordinate these processes. Vega and

Ferdandez (2011) examined the relationship between bilingualism and EF using the WCST and showed that errors on the WCST were correlated with the degree of balance in language proficiencies in Spanish–English bilingual children. Furthermore, studies with between-group designs have shown that bilingual children performed better on the DCCS (Bialystok and Martin 2004; Carlson and Meltzoff 2008; Kalashnikova and Mattock 2014), in comparison to their monolingual counterparts, while other studies showed equivalent performance on the WCST (Ross and Melinger 2017) and DCCS (Bialystok and Shapero 2005; Gathercole et al. 2014). In sum, research assessing complex EF in monolingual and bilingual participants has resulted in mixed findings across age groups and tasks. Furthermore, less is understood on how different degrees of bilingual experience relate to EF performance at different periods of development.

1.3. The current study

The primary objective of the current study was to examine how variation in multilingual experience relates to the development of EF among children and adolescents living in a multilingual community. Of particular interest was the language experiences in social contexts that are most relevant and meaningful for school-aged children. Adopting the frameworks of the ACH, we examined whether dynamic multilingual usage and exposure across home and school were associated with EF performance. The second objective of our study was to characterize the multiple interactional contexts of language use and capture multilingualism as a continuous variable. The third goal of our study was to use multiple tasks tapping into EF and attention. To achieve these goals, we examined age as a continuous variable across a wide age range (6–17 years) to capture the cross-sectional developmental trajectory of EF. We assessed EF performance by using the Conners Continuous Performance Test (CPT-3), and a more complex task that requires the coordination of multiple EF components, namely the WCST. Based on previous research (e.g.

Antoniou et al., 2016), we hypothesized that age, dynamic multilingual experience, and second language (L2) proficiency would positively predict EF performance. Further, we hypothesized that more dynamic multilingual experience across home and school settings and higher L2 proficiency would be associated with better EF performance and that these relationships would be observed after accounting for chronological age of the participants.

2. Method

2.1. Participants

Sixty-seven multilingual children and adolescents (n_{males} = 39, M_{age} = 11.8, SD_{age} = 2.83, age range: 6–17 years) were recruited from the metropolitan area of Montréal via online classified advertisements. All children had exposure to at least two languages. Montréal is a city in the Canadian province of Québec. Although French is the official language of Québec, Montréal is a linguistically diverse city where both French and English are spoken regularly; 59% of Montréal's residents reported conversational fluency in both languages (Statistics Canada, 2016). The majority of the participants were born in Canada (82%), while others were born in Hungary (*n* = 3), France (*n* = 2), Moldova (*n* = 2), Mexico (*n* = 1), U.S. (*n* = 1), Columbia (*n* = 1), Vietnam (*n* = 1), and Singapore (*n* = 1). In terms of language of school instruction, Québec's Charter of the French Language (i.e. Bill 101), passed in 1977, stipulates that only children with an eligibility to study in English can attend English schools, or be enrolled in French-English bilingual or immersion education programs (Coleman 1981). As a result, the majority of students in Montréal attend French-language schools where 54.8% of students do not speak French as their first language (McAndrew and Bakhsaei 2016). In our sample, 22 participants were enrolled in bilingual or immersion programs, 39 were enrolled in a French school and six were enrolled in an English school with French as a subject. Additionally,

47% of participants reported attending schools with a different language of school instructions from their first acquired language (i.e. L1). Moreover, the dominant language spoken by parents to their child at home was different from their child's language of school instructions for 66% of participants.

Forty participants had English as their dominant language while 27 had French as the dominant language, defined as the most frequently used language. Four participants had Spanish (n = 2), Hungarian (n = 1) and Vietnamese (n = 1) as their first language, while 33 had English and 30 had French as their first language. Participants reported speaking a L2 to a wide degree of proficiency; French (n = 30) and English (n = 30) were reported the most as L2, along with Spanish (n = 2), Finnish (n = 1), Romanian (n = 1), and Bengali (n = 1). Additionally, ten participants reported speaking a third language with 10-25% of exposure (n = 8) or with less than 10% of exposure (n = 13), as reported by parents. Two participants reported having no exposure to a L2 outside of school language classes. Half of the participants (51.8%) acquired their L2 before the age of three (M_{AoA} = 3.69, SD = 2.89). Nine participants did not report their age of L2 acquisition but reported having 5-10% of L2 exposure.

2.2. Procedure and Measures

The local university ethics board approved the procedure of the study. Participants provided informed assent prior to task completion. Upon arrival, parents were informed about the research, signed the consent form, and completed a language questionnaire. Participants were instructed and completed two tests assessing EF in their preferred language (English or French), in addition to a measure of general cognitive ability administered by a bilingual research assistant.

2.2.1. Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II)

The cognitive ability of all participants was assessed using the WASI-II (Wechsler, 2011), an individually administered, standardized test. Four subtests gave an estimate of general cognitive ability (Full Scale IQ; FSIQ). Specifically, the vocabulary and similarities subtests provided an estimate for the Verbal Comprehension Index (VCI), a measure of verbal and crystalized abilities, and the block design and matrix reasoning provided an estimate for the Perceptual Reasoning Index (PRI), a measure of nonverbal fluid abilities. The two index scores were converted into age-corrected standardized scores for analysis ($\mu = 100, \sigma = 15$). Participants were administered the English (n = 40) or French (n = 27) version of the WASI-II, according to their preference.

2.2.2. Language and Social Background Questionnaire (LSBQ)

A revised version of the LSBQ (see appendix A) was used to document bilingual experience (Anderson et al. 2018; Luk and Bialystok 2013). The questionnaire was completed on paper by the participant's parent, with research assistants available to answer questions. The LSBQ questions for parents included demographic information, education, and language acquisition history of their children. Moreover, parents reported children's current home language experience including exposure (i.e. language spoken by the mother, father, between parents) and usage (i.e. language used by the child when speaking to family members). Lastly, parents rated their child's language proficiency in understanding, speaking, reading, and writing on a five-point scale.

For each participant, the average of L2 exposure (see Appendix A.1, Part C, Questions 14, 15 & 21) and usage (Part C, Questions 1 and 2) were computed and combined with school language program scores (Part B, Question 18) to create a composite score of their multilingual experience (i.e. multilingual composite score). Higher scores of L2 *exposure* indicated that there was more

use of a child's L2 by the parents or adults at home (maximum = 7). Higher scores of L2 *usage* indicated that a child spoke more in their L2 to adults in their home (maximum = 7). For school language program, participants received a score of one if their school language was the same as their dominant home language, four if they attended immersion or bilingual programs and seven if it was different from home language (i.e. more dynamic multilingual usage throughout the day in separate contexts). The scores were summed for each participant (maximum = 21). Higher scores indicated more dynamic multilingual usage and exposure across home and school contexts.

L2 was defined as the language acquired after a first language or another language simultaneously from birth. Given the sociolinguistic facets of Montréal, participants may have L2 exposure and usage in various degrees, but not all of them are biliterate, especially if they do not receive formal schooling or were just beginning to receive literacy instructions in their L2. Hence, proficiencies in L2 understanding and speaking, but not reading and writing, were used to compute the L2 proficiency score (maximum = 7). This is also related to ACH's focus on spoken language exposure and usage, consistent with previous studies that developed and utilized the Language and Social Background Questionnaire (LSBQ; Anderson et al. 2018; Luk and Bialystok 2013).

2.2.3. Conners Continuous Performance Test (CPT-3)

The CPT-3 (Conners 2014) has been widely used as a measure of attention in developmental studies (Allan et al. 2015). The task requires participants to click the space bar whenever a letter appears on the screen except for the non-target letter 'X'. The task was preceded by a short practice set to make sure that participants understand the instructions. The CPT-3 provides raw scores as well as age-corrected standard scores of detectability (d') and hit reaction time (hit-rates) scores as measures of attention. Detectability is a primary variable of the

CPT-3 that assesses the ability to differentiate non-targets (X) from targets (i.e. all other letters) and it measures the difference between the signal (targets) and noise (non-targets). The greater the difference between the signal and noise distributions, the better the ability to distinguish non-targets and targets. The scores are reverse-scored, hence higher scores of d' indicate worse performance. Hit-rates are the mean response speed of correct responses from the whole task administration measured in milliseconds. Slower response time (i.e. higher scores of hit-rates) is related to inattentiveness. Taken together, lower scores of both d' and hit-rates indicate better performance on the CPT-3. We opted to use raw scores to examine the age-related correlations.

2.2.4. Wisconsin Card Sorting Test (WCST)

An adapted computer-based version of the WCST was administered using the Millisecond Inquisit 5 Lab software. In each trial, the participant was presented with five cards: one response card on the top row and four stimulus cards on the bottom row. Each stimulus card varied in three dimensions (i.e. color, shape, and number of shapes). The three dimensions were combined to provide hints to sort the response card according to the dimension of four stimulus cards. Participants were required to sort the response card to one of the stimulus cards using one of the sorting rules by means of the feedback provided after each sort. To complete one category, participants needed ten consecutive correct sorts. Once a category was completed, the sorting rule changed unbeknownst to the participant such that participants were required to figure out the new sorting rule by monitoring the feedback after each sort. Monitoring is required to learn the subsequent rules through trial and error based on feedback. Once the new rule was acquired, participants held the new rule in their working memory and inhibited the previous dimension (i.e. prepotent/automatic response) in order to correctly sort the cards and continue these processes until the last rule switch or the end of the task. The maximum number of categories possible for

competition is six. Once six categories are successfully completed, the test ends even when the 128-trial maximum is not attained. As a measure of monitoring and an indicator of overall performance on the WCST (Berg 1948), number of total trials and categories completed were the variables for analysis. Lower number of total trials and higher number of completed categories indicate better performance on the WCST.

2.3. Data screening and analysis

The distribution of scores for the multilingual composite score, age, and L2 proficiency were inspected for skewness. Multilingual composite scores had a moderate skewness (skewness = .42). Logarithmic transformation of the multilingual composite variable was conducted to reduce the variable's skewness and to achieve normality. The transformation of the multilingual composite variable reduced skewness value to –.05.

Multiple linear regression model analysis was then conducted to examine how variations in dynamic multilingual experience relates to EF performance. The regression analysis was conducted separately for each of the four EF scores associated with the two EF tasks (WCST and CPT-3). For each EF score, three predictors including (1) age, (2) L2 proficiency and (3) multilingual composite score were entered in the regression model. Tests of multicollinearity revealed variance inflation factors (VIF) smaller than 2.5 for all models, which is below the threshold of 10 (Dormann et al. 2013), suggesting no issues of multicollinearity. Initially, the FSIQ, two interaction terms (i.e. L2 proficiency × Bilingual composite score and Age × bilingual composite score), and the quadratic term for multilingual composite score were included in the regression analysis. However, none of the terms were significant for all the models and hence were removed from the analysis to maintain the parsimony of the models.

3. Results

Table 1 presents the descriptive statistics for demographic and language variables and performance on the two measures of EF. Participant's verbal (M_{VCI} = 96.18 SD = 11.67), non-verbal (M_{PRI} = 105.42, SD = 12.24), and general (M_{FSIQ} = 100.84, SD = 10.1) cognitive ability all fell within the average range. In terms of parental education, 43.3% of parents were at least college educated. Parent's report of participants' L2 proficiency ranged from 1 to 7 (M = 5.11, SD = 1.8). The dynamic multilingual composite score (maximum = 21), consisting of (a) Home L2 usage, (b) Home L2 exposure and (c) School language program, ranged from 3 to 14.7 (M = 6.90, SD = 3.72).

Pearson correlations are reported in Table 2. The log-transformed values of the dynamic multilingual composite scores were used. The correlation analysis with the non-transformed composite score revealed the same results. As expected, age was moderately correlated with d' (r = –.40, p < .001), hit-rates (r = –.58, p < .001), total trials (r = –.55, p < .001) and completed categories (r = .40, p < .01). L2 proficiency was correlated with better d' (r = –.25, p < .05) and higher completed categories (r = –.48, p < .001). Moreover, multilingual composite scores were positively correlated with completed categories (r = .49, p < .01) and negatively correlated with d' (r = –.27, p < .05) and total trials (r = –.35, p < .05). Furthermore, multilingual composite scores were correlated with L2 proficiency (r = .65, p < .001), maternal education (r = .35, p < .01)., and age of L2 acquisition (r = –.54, p < .001). Lastly, there were significant correlations between dependent variables including d' and total trials, (r = .36, p = .01), hit-rates and total trials, (r = .42, p < .01) and hit-rates and completed categories, (r = –.37, p = .01). These results showed that participants with better CPT-3 performance also performed higher on the WCST, portraying the interrelated characteristics of EF on how multiple components of EF such as attention and monitoring are required to solve complex EF tasks.

Table 1

Descriptive Statistics for Demographic and Language Variables, CPT, and WCST scores

Variables	Mean (SD)	95% CI
N = 67		
Demographic variables		
Age	11.8 (2.83)	[11.13, 12.51]
Maternal education	4.13 (.97)	[3.90, 4.37]
Paternal education	4.00 (1.09)	[3.73, 4.27]
FSIQ	100.84 (10.1)	[98.36, 103.31]
VCI	96.18 (11.67)	[93.33, 99.03]
PRI	105.42 (12.24)	[102.43, 108.40]
Language experiences (maximum = 7)		
Home L2 usage	1.63 (1.05)	[1.37, 1.89]
Home L2 exposure	1.91 (1.43)	[1.57, 2.27]
School language score	3.42 (2.62)	[2.77, 4.05]
Language composite variables		
Multilingual composite[1]	6.90 (3.70)	[6.03, 7.83]
Age of L2 acquisition	3.69 (2.89)	[2.91, 4.46]
Language proficiency (maximum = 5)		
L2 Understanding	3.68 (1.28)	[3.40, 4.03]
L2 Speaking	3.53 (1.38)	[3.19, 3.89]
L2 Proficiency[2]	5.11 (1.8)	[4.46, 5.55]
L2 Reading	3.38 (1.42)	[1.85, 2.26]
L2 Writing	3.13 (1.35)	[2.79, 3.47]
CPT-3 (*n* = 66)		
d' score	–1.88 (.95)	[–2.11, –1.64]
hit-rates score	438 (79.60)	[418, 458]
WCST (*n* = 47)		
Total trials	118 (16.62)	[112, 123]
Completed categories	4.26 (1.91)	[3.69, 4.81]

Note: FSIQ – Full Scale Intelligent Quotient; VCI – Verbal Comprehension Index; PRI – Perceptual Reasoning Index; CPT-3 – Continuous Performance Test; WCST – Wisconsin Card Sorting Test

[1]Bilingual composite is a combination score of Home L2 usage, exposure, and school language score

[2] L2 proficiency is a composite score of L2 understanding and speaking scores (maximum = 7)

Table 2

Pearson correlations between independent and dependent variables

	Dependent variables			
Independent variables	CPT– d’	CPT – hit-rates	WCST – Total trials	WCST – Completed categories
Age	–.40***	–.58***	–.55***	.40**
L2 proficiency	–.25*	–.12	–.20	.48***
Multilingual composite	–.27*	–.012	–.35*	.49**
FSIQ	–.08	–.09	–.14	–.20
AoA	–.16	–.21	–.12	.28
Maternal education	–.02	–.10	–.19	.13
Paternal education	–.08	–.02	–.20	.05

Note: *p < .05, **p < .01, ***p < .001

3.1 Predicting Continuous Performance Test

The multiple linear regression model with age, L2 proficiency and linear term for multilingual composite score was significant in predicting d' score of CPT-3. The three predictors explained 23% of the variance, $F(3,62) = 6.23$, $p < .01$, $R^2 = .23$, adjusted $R^2 = .19$ (see Table 3 upper panel). Most importantly, it was found that d' score was significantly predicted by age, $\beta = -.37$, $t(62) = -3.31$, $p < .01$, but not by multilingual composite score, $\beta = -.22$, *ns*, nor L2 proficiency, $\beta < 1$. This demonstrates that the older participants resulted better detectability of targets in the CPT-3. Additionally, the regression model with age, L2 proficiency and linear term for multilingual composite score was also significant in predicting hit-rates on the CPT-3. The three predictors explained 34% of the variance, $F(3,62) = 10.6$, $p < .001$, $R^2 = .34$, adjusted $R^2 = .31$ (see Table 3 lower panel). Hit-rate score was significantly predicted only by age, $\beta = -.60$, $t(62) = -5.63$, $p < .001$. This demonstrates that the younger the participants, the slower the average response speed of correct responses of the CPT-3. In sum, age significantly predicted attention as measured by the CPT-3, with dynamic multilingual experience not being a significant predictor beyond age.

Table 3

Regression models predicting CPT Detectability and Hit Response Time

Variable	Estimate	*SE*	*β*	95% CI		*p*
				Lower	Upper	
CPT Detectability[a]						
Age	–.13	.04	–.37	–.60	–.15	.002**
L2 Proficiency	–.04	.07	–.07	–.33	.19	.60
Multilingual composite	–.85	.49	–.22	–.48	.03	.08
CPT Hit Response Time[b]						
Age	–16.99	3.02	–.60	–.80	–.38	.001**
L2 proficiency	4.50	5.31	.10	–.14	.34	.40
Multilingual composite	–9.02	38.07	–.03	–.26	.21	.81

*p < .05, **p < .01, *** p < .001

[a] *Note.* Constant = .48, $F(3,62) = 6.23$, $p < .01$, $R^2 = .23$, adjusted $R^2 = .19$

[b] *Note.* Constant = .58, $F(3,62) = 10.6$, $p < .001$, $R^2 = .34$, adjusted $R^2 = .31$

3.2 Predicting Wisconsin Card Sorting Test

The multiple linear regression model with age, L2 proficiency and multilingual composite score was significant in predicting total trials of the WCST. The three predictors explained 37% of the variance, $F(3,43) = 8.39$, $p < .001$, $R^2 = .37$, adjusted $R^2 = .33$ (see Table 4 upper panel). Most importantly, it was found that total trials completed was significantly predicted by age, $\beta = -.50$, $t(43) = -3.98$, $p < .001$, as well as multilingual composite score, $\beta = -.33$, $t(43) = -2.21$, $p = 0.03$, but not L2 proficiency, $\beta = .15$, *ns*. This result demonstrates that older participants complete the WCST with a fewer number of trials and a similar relationship was observed for those who had more dynamic multilingual experience. The regression model with age, L2 proficiency and linear term for multilingual composite score was also significant in predicting categories completed. The three predictors explained 35% of the variance in the model, $F(3,43) = 7.70$, $p < .001$, $R^2 = .35$, adjusted $R^2 = .30$ (see Table 4 lower panel). The number of categories completed was significantly predicted only by age, $\beta = .31$, $t(43) = 2.43$, $p < .05$.

Table 4

Regression models predicting WCST Total Trials and Completed Categories

Variable	Estimate	*SE*	*β*	95% CI		*p*
				Lower	Upper	
WCST Total Trials[a]						
Age	–2.98	.75	–.50	–.75	–.24	.001***
L2 Proficiency	1.40	1.39	.15	–.16	.46	.32
Multilingual composite	–23.12	10.88	–.33	–.65	–.02	.03*
WCST Completed Categories[b]						
Age	.20	.08	.31	.05	.56	.02*
L2 proficiency	.17	.16	.17	–.15	.48	.30
Multilingual composite	2.48	1.22	.32	.001	.64	.05

*p < .05, **p < .01, *** p < .001

[a] *Note.* Constant = .61, $F(3,43) = 8.39$, $p < .001$, $R^2 = .37$, adjusted $R^2 = .33$

[b] *Note.* Constant = .59, $F(3,43) = 7.70$, $p < .001$, $R^2 = .35$, adjusted $R^2 = .30$

4. Discussion

The present study examined age-related variation in EF and dynamic multilingual experience in school-aged children and adolescents. Given that children continue to develop their language capacities and EF skills throughout development, we sought to understand the interactions between these experiences and EF in a cross-sectional sample. We investigated whether more dynamic multilingual usage and exposure at home and school, and L2 proficiency would predict attention and monitoring as measured by the CPT-3 and WCST, respectively. Our results showed that EF performance was significantly and positively associated with age. Importantly, the degree of dynamic multilingual experience contributed to performance on EF task of monitoring beyond and above the contribution of chronological age in WCST total trials. However, the multilingual experience did not predict attention measured by CPT-3.

Given the non-linear developmental trajectories of EF and the interrelated nature between components of EF (Best and Miller 2010; Garon et al. 2008), we examined a wide range of children and adolescents and assessed EF components that have been shown in the literature to be closely related to cognitive consequences of bilingualism. Our results showed that the main effect of age was robust, predicting all measures of EF. This is consistent with previous studies demonstrating improved EF with age from early childhood (Doebel and Zelazo 2015), late childhood (Garon et al. 2008) to adolescence (Huizinga et al. 2006; Prencipe et al. 2011). Moreover, more dynamic multilingual experience, denoted by more different multilingual usage and exposure at home and at school, was associated with better monitoring, as demonstrated by successfully completing the task with fewer total trials in the WCST. This finding is in line with previous research that propose monitoring as a consequence of bilingualism (Hilchey and Klein 2011) and comparable to Vega and Ferdandez's (2011) study where degree of balance in bilingual proficiency moderated WCST performance in children. In comparison to the WCST, participant's dynamic multilingual experience did not predict how accurate and fast children performed on the CPT-3. These findings contrast with previous research with bilingual children where the level of attention and bilingualism was related to EF (Chung-Fat-Yim et al. 2020; Sorge et al. 2016). This difference may be in part be explained by the differences in the measures of attention and how children adapted to the linguistic demand in the environment. For example, attention has been measured subjectively through parent and teacher rating scales (e.g. Disruptive Behavior Rating Scale; Willcutt et al. 2005) whereas our study utilized an objective measure of attention. Furthermore, other studies examined attention in samples in a less multilingual environment (Chung-Fat-Yim et al. 2020; Sorge et al. 2016), while the current study examined a sample that lived in a multilingual community.

Notably, there were no interaction effects between age and dynamic multilingual experience in predicting WCST performance. Thus, the association between multilingual experience and monitoring was independent from the effects of age, suggesting that multilingual children with more dynamic multilingual experience across home and school settings are more likely to perform better on EF tasks of monitoring. These results lend support to the ACH (Green and Abutalebi 2013) demonstrating that experiences acquired from being exposed to and managing two languages in dual language context may positively contribute to more domain general monitoring skills in children. The lack of statistically significant results on the WCST categories could be due to the restricted range with number of categories as the outcome.

To date, the majority of studies on multilingualism and EF compared EF performance between monolingual and bilingual groups. Among the limited literature that examined EF and multilingualism on a continuum, Bialystok and Barac (2012) showed that the degree of bilingualism predicted EF performance in 7- to 10-year-olds in Canada who attended schools with language of instruction in either Hebrew or French, in which the majority of children were from English-dominant households. Moreover, two studies with Spanish-English bilingual students in the US have shown associations between degree of bilingualism and EF (Riggs et al. 2014; Thomas-Sunesson, Hakuta. and Bialystok 2018). In contrast to our study, in which the degree of dynamic multilingualism was examined through a usage measure of language experience from parent surveys, Bialystok and Barac (2012) and Thomas-Sunesson, Hakuta, and Bialystok (2018) examined the degree of bilingualism by calculating the difference of receptive vocabulary between the participant's first and second languages. It is likely that both usage and proficiency are correlated. Future research could evaluate the relative importance of these two characteristics of language experience and EF development.

In the current study, all participants had varying exposure to two or more languages due to the sociolinguistic facets of Montréal. To better understand which specific variations in multilingual experience impact EF, the current study extended the framework of the ACH (Green and Abutelebi 2013) to school-aged children and examined whether dynamic exposure to multilingual contexts (at home and at school) was positively associated with EF development. Our study took a novel approach by weighting the influence of home and school language exposure and usage based on the degree of dynamicity across contexts, that is, whether the child used the same languages at home as they did in school or not. In a multilingual environment like Montréal, children's language environment at school contributed more to the variability of dynamic multilingual experience within our sample. In this regard, our finding is consistent with previous research where the amount of daily L2 exposure at school was associated with improved EF performance (Purić, Vuksanović, and Chondrogianni 2017) and cognitive control (Woumans et al. 2016).

Our participants were recruited in the Montréal metropolitan area and hence are exposed to both English and French (for some, their heritage language as well) to different extents at home, in school, and in the community. Therefore, we considered the unique sociolinguistic facets of Montréal by interpreting the history and education policies of Québec and its potential impact in shaping the linguistic and cultural diversity of our sample. Recent statistics have shown that 62.7% of students enrolled in public schools in Montréal were of immigrant origin compared to 45.5% in 1998 (McAndrew and Bakhsaei 2016). Furthermore, Québec not only has a rich history of immigration but also has an educational policy that restricts enrollments in English schools. In our sample, 59% of participants had English and 41% had French as their dominant language. However, the majority of participants attended schools with French as their

main language of instruction (58%) compared to English (9%). In sum, the variability of language and social backgrounds and multilingual experiences shown in our study exemplifies how multilingual children acquire and use their languages dynamically in different contexts (to communicate at home, school and within the community), in different domains of life (home, academics, community), and with different people (family, teachers, friends, people in the community), and how these are related to sociolinguistic factors, reflecting the fluid nature of multilingualism.

5. Limitations and future research direction

This study adds to the current literature on how variations of multilingual experience across contexts relates to children's EF performance. However, there are several limitations. First, the study did not include an objective measure of language proficiency. Although the WASI-II provided an estimate of verbal abilities in the dominant language, it is not an assessment of language proficiency. Further research would benefit from assessing language proficiencies of both languages using language-based measures to fully account for both quantitative and qualitative characteristics of children's degree of bilingualism. Second, the study did not take into account other life experiences such as parent–child attachment, music training and video game experiences that may play a role in children's EF (Bernier et al. 2015; Moreno et al. 2011; Bavelier et al. 2012). Given the domain-general characteristic of EF, future research can examine important life experiences as potential modulating variables of EF. Finally, another limitation is the relatively small sample size in comparison to the wide age range of participants. Although assumptions for statistical tests were carefully considered and met, more participants would be needed in future studies to fully capture the variability of both current and past language experiences and the development of EF. Likewise, longitudinal or cross-sectional

studies can better examine the dynamic nature of bilingualism and developmental trajectory of EF and also control for random variation across time to better isolate the impact of bilingualism.

6. Conclusion

The present study adopted a multidimensional approach to demonstrate the variation of multilingualism as a dynamic experience in children and adolescents from a multilingual community, and how variability of multilingualism relates to EF. We examined the variability of dynamic multilingual experience within a multilingual sample and considered the role of the sociolinguistic factors. The results of the current study extend the framework of the ACH to children and adolescents, who are developing their language and EF capacities, and its applicability in multiple social contexts. Further, our finding highlights the dynamic nature of multilingualism in developing multilinguals and the significance of considering various dimensions of multilingual experience relevant to their characteristics. In other words, our study demonstrated the linguistic, cognitive, and demographic nuances associated with multilingual experience. A comprehensive view of multilingualism will allow future research to yield valuable insights on the sources of variations within language experience and enrich the characterization of multilingualism to better delineate how differences in these experiences may relate to EF development and other cognitive consequences of multilingualism.

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Appendix A

Language and Social Background Questionnaire

Part A – Background

1. Today's date: _____
day **month** **year**

2. Completed by: Mother ☐ Father ☐ Other ☐ (please specify) _____

The following information refers to your CHILD:

3. First name: _____ Last name: _____

4. Date of birth _____ **5.** Gender: _____ **6.** Grade: _____
day **month** **year**

7. Country of birth: _____

8. Has your child lived outside of Canada? **yes ☐ no ☐**
If yes, please indicate the country and the duration. _____

The following information refers to the PARENTS:

9. Country of birth of MOTHER: _____

If not born in Canada, when did the mother come to Canada? (Month/Year) _____

What language(s) did the mother grow up speaking? _____

List the languages known by the mother, *in order of fluency (most fluent to least fluent)*:

_____

10. Country of birth of FATHER: _____

If not born in Canada, when did the father come to Canada? (Month/Year) _____

What language(s) did the father grow up speaking? _____

List the languages known by the father, *in order of fluency (most fluent to least fluent)*:

_____

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

11. MOTHER
1.____ No high school diploma 2. ____High school graduate 3. ____Some college or college diploma
4. ____Bachelor's degree 5. ____Graduate or professional degree. Occupation:_____

12. FATHER
1.____ No high school diploma 2. ____High school graduate 3. ____Some college or college diploma
4. ____Bachelor's degree 5. ____Graduate or professional degree. Occupation:_____

Revised from Anderson et.al., 2018; Luk & Bialystok, 2013 Page 1 of 3

Part B – Child's Language Experience

13. Please list the language(s) your child is exposed to and rate your child's understanding, speaking, reading, and writing abilities for each language(s).

Understanding

Name language(s)	Poor	Fair	Moderate	Good	Excellent
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐

Speaking

Name language(s)	Poor	Fair	Moderate	Good	Excellent
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐

Reading

Name language(s)	Poor	Fair	Moderate	Good	Excellent
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐

Writing

Name language(s)	Poor	Fair	Moderate	Good	Excellent
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐

14. Which language did your child first speak? _____

15a. If your child speaks more than one language, where did they first start to learn the other language(s)?

_____

15b. What age did they first start to learn the language(s)? _____

16. Out of 100%, Please allocate percentages of overall exposure for each language within the past 6 months. (e.g., 50% English, 50% French). _____

17. Is your child enrolled in an immersion program at school? **yes** ☐ **no** ☐

If **yes**, which immersion program? _____

If **no**, what is the language of instruction at school? _____

18. Is your child taking any other language classes at school? _____

19. Does your child attend any language or school program other than regular school? **yes** ☐ **no** ☐

If **yes**, which program and how often? _____

20. Is there another relative (e.g., grandparent) who lives in the home? **yes** ☐ **no** ☐

If **yes**, what are the languages spoken by that relative? _____

1

Part C – Language in the Home

For each of the following, please indicate with a check mark (√) the use of language in your hom e for that activity. If a question does not apply to your family, please indicate by w riting N/A.

Questions about the CHILD	**All English**			**Half English/ half other language(s)**			**Only in the other language(s)**
Language **CHILD** speaks to:	1	2	3	4	5	6	7
1. Mother	☐	☐	☐	☐	☐	☐	☐
2. Father	☐	☐	☐	☐	☐	☐	☐
3. Siblings	☐	☐	☐	☐	☐	☐	☐
4. Maternal grandparents	☐	☐	☐	☐	☐	☐	☐
5. Paternal grandparents	☐	☐	☐	☐	☐	☐	☐
6. Other relatives (aunts, uncles etc.)	☐	☐	☐	☐	☐	☐	☐
7. Friends	☐	☐	☐	☐	☐	☐	☐
Language **CHILD** uses for:							
8. Reading	☐	☐	☐	☐	☐	☐	☐
9. Listening to the radio/music	☐	☐	☐	☐	☐	☐	☐
10. Watching TV/video	☐	☐	☐	☐	☐	☐	☐
11. Searching the internet (e.g., Google, Facebook)	☐	☐	☐	☐	☐	☐	☐
Overall, language your **CHILD** uses to speak:							
12. At home	☐	☐	☐	☐	☐	☐	☐
13. Within your community/local environment	☐	☐	☐	☐	☐	☐	☐

Questions about the FAMILY

Language spoken **IN THE HOME** to the child by:	1	2	3	4	5	6	7
14. Mother	☐	☐	☐	☐	☐	☐	☐
15. Father	☐	☐	☐	☐	☐	☐	☐
16. Siblings	☐	☐	☐	☐	☐	☐	☐
17. Maternal grandparents	☐	☐	☐	☐	☐	☐	☐
18. Paternal grandparents	☐	☐	☐	☐	☐	☐	☐
19. Other relatives (aunts, uncles etc.)	☐	☐	☐	☐	☐	☐	☐
20. Neighbours/friends/ other caregivers	☐	☐	☐	☐	☐	☐	☐
Language spoken **IN THE HOME** between:							
21. Parents/Spouses	☐	☐	☐	☐	☐	☐	☐
22. Siblings	☐	☐	☐	☐	☐	☐	☐
23. Maternal grandparents	☐	☐	☐	☐	☐	☐	☐
24. Paternal grandparents	☐	☐	☐	☐	☐	☐	☐
25. Other relatives (aunts, uncles etc.)	☐	☐	☐	☐	☐	☐	☐
26. Neighbours/friends	☐	☐	☐	☐	☐	☐	☐
Language used **IN THE HOME** for:							
27. Reading	☐	☐	☐	☐	☐	☐	☐
28. Listening to the radio/music	☐	☐	☐	☐	☐	☐	☐
29. Watching TV/video	☐	☐	☐	☐	☐	☐	☐
30. Searching the internet (e.g., Google, Facebook)	☐	☐	☐	☐	☐	☐	☐
31. Reading stories to the child	☐	☐	☐	☐	☐	☐	☐

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