Bilingual Outcomes for a Child with Down Syndrome in the

Early French Immersion Program

by

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*For my brother, Dr. Jonathan Martin.*

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# ABSTRACT

Children with Down syndrome (DS) seem to rarely participate in French Immersion (FI) programs. The purpose of the present study was to examine the longitudinal outcomes of one participant with DS in a New Brunswick FI program and to document whether participation in FI leads to cognitive advantages in the EF skills after completing 7 years in the program. Results showed the bilingual participant was continuing to develop his English language and reading skills from T1 to T2, but his French language and reading skills had stalled. There was no significant difference in EF skills found between the bilingual participant and the monolingual comparison group. Although no evidence of a bilingual advantage was found in this study, the results of the current study support the findings of other studies of bilingualism in DS (Kay-Raining Bird *et al*., 2005; Edgin *et al*., 2011) that individuals with DS can and do become bilingual, with no detriment to their first language, and extends the findings to bilingual acquisition in a FI context.

## LIST OF ABBREVIATIONS USED

| | |
|---|---|
| A-E | age-equivalent |
| BRIEF | Behaviour Rating Inventory of Executive Function |
| CA | chronological age |
| CELF-IV | Clinical Evaluation of Language Fundamentals-IV |
| CELF-IV CDN-F | Évaluation clinique des notions langagières fondamentales, version for Francophone Canadians |
| EF | executive functioning |
| FI | French immersion (Grade 3 Entry) |
| DS | down Syndrome |
| DCCS | Dimensional Change Card Sort |
| FIST | The Flexible Item Selection Task |
| GNG | Go/No Go Paradigm |
| IQ | intelligence quotient |
| NVMA | non-verbal mental age |
| SAS | standard age score |
| SB-IV | Stanford-Binet Intelligence Scale-IV |
| TD | typically-developing |
| WIAT-II | Test de Rendement Individual de Wechsler-II, version for Francophone Canadians |
| WRMT-III | Woodcock Reading Mastery Test-III |
| PPVT | Peabody Picture Vocabulary Test |
| WRAT | Wide Range Achievement Test |
| WISC-V | Weschler Intelligence Scale for Children-V |

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# CHAPTER 1: INTRODUCTION

Children with Down syndrome (DS) seem to rarely participate in French Immersion (FI) programs. A reason for this may be that parents and educators fear that opting to learn a second language may negatively influence their child's academic learning and hinder their native language growth. To date, there is no published research on bilingual children with DS with regards to their outcomes in FI programs. Further, while the literature indicates that bilingualism may lead to executive function (EF) advantages in typically developing children who acquire a second language (Chan, 2005; Goetz, 2000; Adesope *et al*, 2010, although see de Bruin, Treccani, & Della Sala, 2015; Paap, Johnson, & Sawi, 2015; Hilchey & Klein, 2011; for contrary evidence), to date no studies have documented cognitive advantages in bilingual children with DS. The goal of this study is to document the success one child with DS has in FI over a two-year period and whether one participant with DS participating in this program shows advanced skills in EF relative to a matched group of monolinguals with DS. By addressing these issues, this study will provide a foundation for continued research into the outcomes of children with DS in FI programs and could also help educational providers make informed decisions regarding their educational placements.

# CHAPTER 2: BACKGROUND AND LITERATURE REVIEW

## 2.1 Bilingualism in Canada

Canada has two official languages: English and French. The Official Languages Act of Canada (2015) mandates the equality of both languages in terms of status, use, and rights across the country and within institutions, including the Canadian education system's responsibility to provide opportunities for all to learn both English and French. The FI program in Canada was developed to help children from an English majority language background acquire French, however recently, children from minority first language backgrounds have increasingly been accessing the program. In these programs, second language exposure is used as a medium for subject-matter instruction, with the notion that the participants will learn language by using it. Across Canada, there is some variability amongst immersion programs offered and the amount of French language instruction students receive varies across provinces. For the purposes of this study, we are concerned only with FI in New Brunswick.

New Brunswick's FI program begins in Grade 3, with the students completing the academic year with 80% of French classroom instruction. The percentage of French instruction decreases to a minimum of 70% in grades six through eight, and reduces further to a minimum of 50% in the ninth and tenth grades. After this point, French becomes optional for students (Government of New Brunswick, 2013). The Government of New Brunswick states that the FI programs can be adapted for children with learning difficulties so that every individual has the opportunity to learn both official languages.

## 2.2 FI Outcomes for Typically Developing Children

Research shows that typically developing (TD) students in FI programs can attain a high level of proficiency in the French language; a level significantly higher than non-immersion students who receive one hour of second language instruction per day (Lyster, 2007; Genesee & Lindholm-Leary, 2013; Lazaruk, 2007). Although TD students attain high levels of French in domains of language comprehension (listening and reading) and production (speaking and writing), they fall short of native-like proficiency in French oral production skills (Lambert *et al*., 1993; Genesee *et al.*, 2013).

With respect to English reading skills, TD FI students often score lower on reading and writing tests in the early primary grades in programs where instruction in English language arts is not introduced from the beginning (Genesee *et al.*, 2013). However, this lag disappears after one year of English language arts instruction and by twelfth grade, there is no significant difference in the written English skills of FI students compared to those in all-English classrooms, when matched on intelligence and socio-economic status (Genesee, 2004; Lambert & Tucker, 1972; Swain & Lapkin, 1982). With respect to other academic skills such as mathematics and science, TD FI students perform equally as well as students in English-only programs, and sometimes better (Lambert *et al.*, 1993), even though they are schooled in their second language.

To summarize, TD children in FI programs achieve high proficiency in the French language, which is higher than non-immersion students receiving conventional second language core class instruction but lower than native speakers, and there are no negative effects documented on English language skills or other academic subjects from participating in an immersion program.

**2.3 Bilingualism and Bilingual Advantages in TD Children**

Bilinguals vary on a number of characteristics. Simultaneous bilinguals are those who are exposed to both languages at birth or shortly after and learn both languages at the same time. Sequential bilinguals are those who are exposed to one language from birth and become somewhat proficient in this language before a second language is introduced and acquired. Either type of bilingual may have equal proficiency in both languages, termed balanced bilingualism, or have one language that they are more proficient in than the other, termed the dominant language. Children in FI are sequential bilinguals because they speak one language from birth and only begin to learn French after they enter school. This study will assess the English and French language and reading skills of one individual with DS who has been attending FI for 7 years, so has acquired some proficiency in his second language, French. Although his French language and reading skills are developing, it is likely that English remains his dominant language.

The literature has demonstrated that there may be cognitive advantages to being bilingual, including, but not limited to, better developed executive functioning (EF) (Chan, 2005; Goetz, 2000; Adesope *et al*, 2010). EF is the set of processes responsible for the conscious control of thoughts and actions (Poulin-Dubois *et al.*, 2011), of which there are three generally agreed upon core processes - the ability to suppress irrelevant stimuli while attending to those that are relevant (inhibitory control), the ability to switch between different mental concepts and think about several mental concepts simultaneously (cognitive flexibility), and the ability to manipulate and control cognitive resources including linguistic processes (working memory) (Diamond, 2013). These executive functions help children to manage their behaviour, maintain focused attention, think flexibly, and retain and retrieve information. Therefore an individual's EF skills are important for their academic success and emotional intelligence.

Bilingual advantages in EF are hypothesized to exist for the following reasons.

Bilinguals may have increased inhibitory control because they must inhibit the use of one language in order to communicate in the other. Bilinguals may have increased cognitive flexibility because they must switch between both languages depending on the language spoken by the communication partner. Finally, bilinguals may have increased working memory because they must access two different language systems concurrently (Adesope *et al.*, 2010; Morales *et al.*, 2014).

### 2.4 Evidence for Bilingual Advantages in EF Tasks

There are a few common tasks that have been used to measure executive functioning in monolinguals and bilinguals. There is a lack of consistency in the literature in terms of views on which aspect of EF each task measures and it is important to recognize there is no way to purely measure one without some component of another. Studies have attempted to measure inhibitory control with Go/No-Go, Simon, and flanker tasks, cognitive flexibility with the Dimensional Change Card Sort (DCCS), and working memory with the Forward and Backward Digit Span tasks.

#### *2.4.1 Bilingual Advantages in Inhibitory Control*

There are aspects of inhibitory control commonly measured in bilingual studies: response inhibition and interference inhibition. Response inhibition tasks, such as the Go/No-Go, require inhibiting the performance of a familiar response. In a Go/No-Go task (Jacques and Zelazo, 2001), the participant is instructed to press a key when a sun appears on the computer screen and withhold from pressing the key when a moon appears. Both the accuracy rate and response times are calculated. This type of inhibition has not been found to increase with bilingualism (Nicolay & Poncelet, 2013).

Unlike tasks that test response inhibition, tasks that test interference inhibition have been successful at demonstrating bilingual advantages. These tasks require inhibiting misleading and distracting information to solve a conflict. There are two widely used tasks to test interference inhibition, the Simon and the flanker; both compare reaction times between congruent and incongruent trials. Simon tasks are based on the Simon effect, which is the finding that responses are faster when a stimulus occurs in relatively the same location as the response (Appelblad, 2015). In a typical computerized Simon task (Martin-Rhee & Bialystok, 2008), the participant is instructed to press the red button (a key marked with a red sticker on the right side of the keyboard) when they see a red square and to press the blue button (a key marked with a blue sticker on the left side of the keyboard) when they see a blue square. The squares appear one at a time on either the far left or far right hand side of the screen. In a congruent trial, the square appears above the button of the same colour (e.g. red square above red button), and in incongruent trials, the square appears above the button with the opposite colour (e.g. red square above blue button). In computerized versions of flanker tasks, a participant is shown a computer screen with an arrow pointing either left or right and is instructed to hit a corresponding key to the direction the arrow points (i.e., press the left button if the arrow is pointing left, press the right key if the arrow is pointing right). The arrow is 'flanked' by four other arrows, two on each side, that either point in the same direction as the middle arrow (congruent trials) or in the opposite direction (incongruent trials). The participant is asked to hit the key corresponding to the direction the middle arrow faces while disregarding the other distracting arrows. Like Simon tasks, the responses tend to be faster for congruent trials than incongruent trials.

In a study by Bialystok *et al.* (2005), a Simon task was administered to a group of monolingual children and a group of simultaneous French-English bilingual school-aged children (recruited from French after-school childcare programs). They found that the bilingual group responded more rapidly than the monolingual group on both congruent and incongruent trials. This advantage in reaction time was also found in a study by Martin-Rhee *et al.* (2008). In their study, a similar Simon task was administered to two groups of 4- and 5-year old children, simultaneous bilinguals and monolinguals. Their results revealed faster reaction times for the bilingual group on both congruent and incongruent trials but only when the task required an immediate response. When the child was required to wait 500 ms before responding, both monolingual and bilingual groups scored comparatively. This suggests that bilinguals have the ability to inhibit irrelevant information and attend to the task more readily than monolinguals.

Studies on sequential bilinguals have attempted to replicate this advantage in reaction times but have been unsuccessful. In a study by Nicolay *et al.* (2013), scores on a flanker task were compared between a group of children in grades 2 and 3 who had completed three years of an FI program, and a group of monolingual children, matched on socioeconomic status and verbal and nonverbal intelligence. Both groups responded faster to congruent trials than incongruent trials but there was no effect of language condition. The authors suggested that three years of an immersion program may not have been sufficient exposure to create advantages typically seen in simultaneous bilinguals.

Since advantages in inhibitory control have been found in simultaneous bilinguals, but not in sequential bilinguals after three years of immersion experience, a question raised is what length of time spent in a bilingual education program is required before advantages in inhibitory control are evident? This question was addressed by Bialystok and Barac (2012). Their study looked at 100 children from primarily English-speaking homes in grades two and three attending a Hebrew immersion program. The children had varied home languages and because they could join the immersion program at any time, they had varied lengths of time spent in the immersion environment. The authors used a regression analysis to determine the relation between scores on a flanker task, used to test inhibitory control, and relevant background features, including nonverbal intelligence (measured with K-BIT), English vocabulary proficiency (measured with PPVT), age in months, length of time spent in a bilingual educational environment (measured in years), and degree of bilingualism (determined by the ratio of Hebrew PPVT score to English PPVT score). The results showed age, degree of bilingualism, and years spent in a bilingual educational program were all significant positive contributors to performance on flanker task scores. Although this study did not compare bilingual scores to monolinguals, and therefore could not address the hypothesis that bilinguals have an advantage compared to monolinguals, these positive correlations suggest a tendency for EF scores on the flanker task to increase as children become more bilingual. The present study used a Go/No-Go task to test the participants for response inhibition and a flanker task to test for interference inhibition.

### *2.4.2 Bilingual Advantages in Cognitive Flexibility*

Tasks that measure the ability of a participant to readily switch between different mental concepts has been referred to in the literature by a variety of different names, including cognitive flexibility, attentional control, and attentional inhibition. Two tasks that test this EF are the Dragon's House and the Dimensional Change Card Sort. In the Dragon's house task (Nicolay *et al*., 2013), a child sits in front of a computer and on the screen a blue dragon and a green dragon appear simultaneously. The child is shown two buttons on a keyboard: a left button and a right button. In the first trial, the child is instructed to press the button corresponding to the side the green dragon is on (e.g. if the green dragon is on the left of the blue dragon, the left button should be pressed). In the next trial, the child is instructed to press the button to corresponding the side the blue dragon is on. These trials continue to alternate between target dragons and the side the dragons appear in is unpredictable. Reaction time and number of errors are scored as measures of cognitive flexibility. In the Dimensional Change Card Sort task (Zelazo, Frye, & Rapus, 1996), the participant is given a deck of cards that have pictures of varying shapes and colours, and two compartments in which to sort these cards. Each compartment is marked with a target stimulus (e.g. a blue square in one compartment and a red triangle in the other). In a pre-switch phase, the participant must sort the cards based on one dimension (e.g., the colour of the pictures). In a post-switch phase, the participant must use the same cards but sort them on another dimension (e.g., the shape of the pictures). This means they must reassign their cards to the opposite compartment. The ability to correctly switch sorting dimensions, as opposed to perseverating on the initial sorting scheme, is the measure of cognitive flexibility.

Simultaneous bilinguals have frequently demonstrated advantages in accuracy rates in post-switch trials for Dragon and DCCS tasks (Bialystok 1999; Carlson & Meltzoff, 2008; Bialystok & Martin, 2004). For example, Bialystok (1999) found that simultaneous bilinguals were more accurate than monolinguals in switching between mental concepts on the DCCS task. Their study included 60 children, bilinguals and monolinguals in two age groups (younger group had a mean age of 4, and the older group had a mean age of 5,5). The authors found the bilinguals and older children outperformed monolinguals and younger children respectively.

For sequential bilinguals, studies using the Dragon's House task have also shown advantages in cognitive flexibility. Nicolay *et al.* (2013) compared reaction times on the Dragon's House task between a monolingual group of grade 2 and 3 children and a bilingual group of same-age children who had completed three years of an immersion program. The results showed the immersion group had faster reaction times than the monolingual group, indicative of better cognitive flexibility even after only three years of second language exposure. In this study, cognitive flexibility was tested with a computerized variation of the DCCS task.

### *2.4.3 Bilingual Advantages in Working Memory*

Forward or backward Digit Span tasks are often used to test working memory, but these tasks have not been successful at finding a bilingual advantage (Martin-Rhee *et al.*, 2008; Bialystok *et al.*, 2005; Bialystok *et al.*, 2004). In a Forward *Digit Span* task *(WISC-IV,* Weschler, 2004), a participant is read a series of digits and is asked to repeat them. The trials begin with a series that is two digits in length, and each subsequent trial adds one more digit. Two trials are given at each length and the task ends when a child fails both trials at a given length. One point is awarded for every correctly reproduced sequence, for a possible total of two points for each sequence. Given bilingual advantages have not been documented for this task, the Forward Digit Span (or a similar task) is frequently used as a measure to equate monolingual and bilingual groups (Martin-Rhee *et al.*, 1998; Bialystok, 1999; Bialystok *et al.*, 2005; Bialystok *et al.*, 2004). We used the Forward Digit Span task in this study to compare the working memory skills of our bilingual participant to our monolingual group and the Backward Digit span task to investigate a possible bilingual advantage for working memory.

## 2.5 Language Development in Children with DS

Children with DS present with a number of cognitive and language deficits. Children with DS most often have a moderate intellectual disability. Compared to nonverbal mental-age matched peers, these children tend to have delayed language abilities, predominantly in expressive language skills and particularly in the morphosyntactic domain (Chapman, 2003; Chapman & Kay-Raining Bird, 2011). Receptive vocabulary is a particular strength for this population and abilities in this area are often commensurate with nonverbal mental age (NVMA). Given their cognitive delays, NVMA is often a better predictor of language development than chronological age (Chapman, Schwartz, Kay-Raining Bird, 1991).

### 2.6 Executive Functioning and DS

Given that they have an intellectual disability, it is perhaps not surprising that people with DS also show deficits in EF skills. Lanfranchi *et al.* (2010) compared adolescents with DS to typically developing children, matched on NVMA. Their study found deficits in the group with DS on measures of inhibitory control (measured with a Stroop task), cognitive flexibility (measured with a Rule Card Shift task), and working memory (measured with verbal and visuo-spatial dual tasks). These deficits were replicated with similar tasks by Rowe, Lavender, & Turk (2006), who compared adults with DS to participants with intellectual disability but without DS, matched on age and receptive vocabulary.

### 2.7 Bilingualism and DS

There is a growing body of research to show that children with DS can and do become bilingual (Edgin et al., 2011; Kay-Raining Bird, Cleave, Trudeau, Thordardottir, Sutton, & Thorpe, 2005; Feltmate & Kay-Raining Bird, 2008). The research also shows that becoming bilingual does not have a detrimental effect on the majority (and dominant) language development of bilinguals with DS (Kay-Raining Bird *et al.*, 2005).

There is only one published study that has researched EF in bilingual children with DS. Edgin *et al.* (2011) studied the neuropsychological functioning of children and adolescents with DS (age range of 7-18 years, mean age of 13) with and without second language exposure, matched on chronological age, IQ, and social background factors. Measures were a battery of tests including the Behaviour Rating Inventory of Executive Function (BRIEF) and Dimensional Change Card Sort task. This study found no significant differences between the monolingual and bilingual groups on any measure of verbal or prefrontal skills (i.e., working memory, inhibitory control, or cognitive flexibility). These authors did not control for the duration of second language exposure or measure the minority language abilities of the participants, which may have explained their inability to detect a group difference on these measures (i.e., only those with greater exposure might show the expected advantages).

**2.8 Early French Immersion and At-Risk Children**

FI outcomes for children with language or cognitive disabilities have rarely been studied. Genesee (2007) reviewed the literature on at-risk FI students, defined as "those with language, reading, and academic difficulties or who are likely to experience such difficulties, whether they stem from what might be considered clinical factors (reading disability or language impairment) or from non-clinical factors (generally low levels of academic ability)" (p. 656). He concluded that at-risk students were not at differentially greater risk for academic difficulties than similar students in programs where instruction was in English only. Furthermore, the studies he reviewed showed that at-risk children in

FI demonstrated better French language skills compared to students in the English-only programs with similar profiles who took a French class as a subject.

A study by Bruck (1978) provided evidence that children with language impairments can succeed in FI. The author looked at the development of children with language impairments from kindergarten to grade 3 in FI and English-only programs. The FI children with language impairment showed similar English vocabulary (measured with the WISC and PPVT), cognitive (measured with the WISC), and academic (measured with the Metrop, WRAT, and Spache) abilities, compared to English-only instructed children with language impairments. These results indicated that FI children with language impairment were developing academically and in the majority language at a similar rate to their monolingual peers regardless of their participation in an FI program. In the same study, the FI children with language impairments were also tested for their French language development (measured with the Ontario Institute for Studies in Education French Listening Comprehension Test and teacher ratings/interviews). Their French comprehension scores showed a lag in French oral comprehension skills compared to children in FI with normal language development until grade 3, at which point the children with language impairments scored similarly to the control group. The teachers reported that the French oral production skills of the children with language impairments also lagged behind the skills of the control group but by grade 3, the children with language impairments were able to comprehensibly express themselves in French most of the time.

The French comprehension scores and teacher reports showed that these children with language impairments were learning more French than children with and without language impairment in the English-only programs, although not to the same proficiency level as FI children without language impairment. This disparity is related to the basic nature of their language learning difficulty but it is nevertheless admirable that these children are successfully learning two languages in an immersion context. Furthermore, these results are encouraging because they show that children with language disabilities can acquire linguistic, cognitive, and academic skills similar to what they would be expected to achieve if they had been placed in an English-only program, with the added benefit of learning a second language.

### 2.9 FI and Children with DS

There is no published research that studies the outcomes of children with DS in FI. One unpublished case study by Hodder, Merritt, & Kay-Raining Bird (2015) documented the French and English abilities of a boy with DS who at the time of the study, was in his fifth year of FI and was enrolled in grade 6. The results of their study showed he was successfully developing language and reading skills in both French and English, but no data on his EF skills were collected. This same bilingual boy participated in the present study, allowing for longitudinal analyses of his French and English language and reading skills. In addition, his EF abilities were tested and compared to a matched group of monolinguals.

Since children with DS as a group have difficulties with EF, and becoming bilingual through FI potentially strengthens EF after a certain period of exposure, at least for typically developing children, then it is possible that participating in FI might be particularly advantageous for children with DS because it might improve deficits in at least some EF areas.

### 2.10 Purpose of present study

The purpose of the present study was to examine the longitudinal outcomes of one participant with DS in a New Brunswick FI program and to document whether participation in FI leads to cognitive advantages in the EF skills of one participant with DS after completing 7 years in the program.

*2.10.1 Research Questions*

1. What progress did the participant make in French and English language/reading skills between grades 6 and 8, following 5 years and 7 years of FI respectively?

2. What are the participant's English language/reading skills compared to a monolingual group with DS, matched on chronological age?

3. Does the participant show advantages in inhibitory control, cognitive flexibility, and/or working memory, compared to a monolingual group with DS, matched on chronological age?

*2.10.2 Research Hypotheses*

1. The participant will show increased French language/reading development compared to the results from Hodder et al. (2015).
2. The participant will show increased English language/reading development compared to the results from Hodder et al. (2015).
3. The participant will show comparable English language/reading development to the monolingual group with DS, matched on chronological age.
4. A similar pattern of EF abilities will be evident in the bilingual participant with DS as has been reported in research on bilingual EF advantages in the typically developing population of sequential bilinguals. Specifically*:*

The participant will show increased cognitive flexibility, compared to a monolingual group with DS, matched on chronological age.

The participant will not show increased inhibitory control or working memory, compared to a monolingual group with DS, matched on chronological age.

# CHAPTER 3: METHODS

## 3.1 Participants

### *3.1.1 Bilingual Participant*

One bilingual boy with DS (Trisomy 21), 14 years of age, currently enrolled in grade 8 in a New Brunswick FI program was recruited as the bilingual participant. He had previously participated in a research study (Hodder et al., 2015) after having completed 5 years of FI. As residents of a bilingual community, his parents reported in the interview portion of that research study that they felt it was important their son be bilingual for independence and employment opportunities in their community. The family spoke primarily English at home, as his father was a monolingual-English speaker[1]. His mother is a fluent bilingual in English and French with a bachelor-degree in education. The bilingual participant began FI in Grade 3, repeated Grade 3 once, and was in Grade 8 at the time of the present study. Data collected by Hodder et al. (2015) served as the time 1 (T1) data. Time 2 (T2) was collected after he had completed an additional 2 years, for a total of 7 years of FI.

### *3.1.2 Monolingual Comparison Group*

A group of 8 monolingual English-speaking participants with DS (7 with Trisomy 21 and 1 participant with a translocation) were recruited to serve as a comparison group. The participant with translocation (M7), performed similarly to other monolingual participants. Inclusion criteria included a diagnosis of Down syndrome, bilingual participant's age +/- three years, English as the first and only language, and mother's

[1] The bilingual participant's father died between time 1 and time 2 of testing.

educational level of high school equivalent or higher. Participants were excluded if they were exposed regularly to another language outside of the school's core French class. Participants were between the ages of 12;1 and 17;9. A ninth monolingual participant with DS was recruited however his testing was discontinued, as he was unable to complete most tasks. See Tables 1 and 2 for individual participant and group statistics for age, non-verbal mental age (NMVA) and standard age score (SAS) for two subtests of the Stanford-Binet Tests of Intelligence-IV and Forward Digit Span (i.e., short-term memory) performance (see Measures section for descriptions of latter two tests).

**Table 1** Individual participant variables

| Participant | Gender | CA (year; months) | NVMA [1] (year; months) | Raw Scores for Forward Digit Span[2] (A-E score) |
|---|---|---|---|---|
| Bilingual Participant | M | 14;3 | 5;8 | 5 (<6;2) |
| Monolingual Participant #1 (M1) | F | 12;1 | 5;1 | 4 (<6;2) |
| Monolingual Participant #2 (M2) | F | 14;7 | 4;1 | 5 (<6;2) |
| Monolingual Participant #3 (M3 | M | 14;2 | 5;0 | 4 (<6;2) |
| Monolingual Participant #4 (M4) | M | 17;1 | 7;11 | 7 (7;2) |
| Monolingual Participant #5 (M5) | M | 15;9 | 4;9 | 3 (<6;2) |
| Monolingual Participant #6 (M6) | M | 17;9 | 4;8 | 2 (<6;2) |
| Monolingual Participant #7 (M7) | F | 16;8 | 4;9 | 6 (6;2) |
| Monolingual Participant #8 (M8) | M | 12;2 | 6;5 | 6 (6;2) |

*Notes*. CA = Chronological age; A-E= Age-equivalent 1 NVMA = Non-verbal mental age was measured by obtaining age-equivalent scores on two subtests of the Stanford-Binet IV (Pattern Analysis and Bead Memory) and averaging the two scores. 2 Short-term memory was measured by calculating age-equivalent scores from raw scores obtained on the Forward Digit Span Task (WISC-IV).

**Table 2** Characteristics of bilingual participant compared to monolingual participants as a group.

| Participants | CA (years; months) *M (SD)* | NVMA[1] (years; months) *M (SD)* | SAS[2] *M (SD)* | A-E for Forward Digit Span[3] (years; months) *M (SD)* |
|---|---|---|---|---|
| Bilingual Participant | 14;3 | 5;8 | 51 | <6;2 |
| Monolingual Comparison Group (*n*=8) | 15;1 (2;2) | 5;4 (1;2) | 47.13 (10.73) | 6;3 (0;4) |

*Notes*. CA = Chronological age; M = mean; SD = standard deviation; A-E = age-equivalents; NVMA = Non-verbal mental age; SAS = Standard age scores. 1NVMA was measured by obtaining age-equivalent scores on two subtests of the Stanford-Binet IV (Pattern Analysis and Bead Memory) and averaging the two scores. This measure was calculated for each of the monolingual participants and then averaged to obtain a mean non-verbal mental age for the group. 2Composite standard age scores were calculated for each of the monolingual participants and then averaged to obtain a mean standard age score for the group. 3 Short-term memory was measured by calculating age-equivalent scores from raw scores obtained on the Forward Digit Span Task (WISC-IV) and then averaging them to obtain a mean age-equivalent score for the group.

As Tables 1 and 2 show, the bilingual participant is comparable to the monolingual comparison group on all variables. His chronological age, non-verbal mental age, standard age score, and short-term memory scores are all within one standard deviation of the mean of the monolingual group. The participants in this study range from mild to severe intellectual disability, based on SAS obtained from the Stanford-Binet-IV.

### 3.2 Recruitment

The bilingual participant had previously participated in a research study and his family had agreed to be contacted for future studies. All monolingual participants were recruited through Special Olympics Nova Scotia or through word of mouth, following ethics approval from Dalhousie University.

### 3.3 Measures

#### *3.3.1 Non-verbal Mental Age (NVMA)*

Two subtests of the *Stanford-Binet Intelligence Scale-IV (Thorndike et al., 1986)* were used to calculate NVMA and SAS. The Bead Memory subtest was used to measure visual short-term memory. The participant was asked to recall the identity of one or two beads exposed briefly (items 1 through 10) or asked to reproduce a sequence of beads in a precise order (items 11 through 42). The Pattern Analysis subtest was used to measure abstract/visual reasoning. The participant was asked to complete form boards (items 1 through 6) and replicate visual patterns through block manipulations (items 7 through 42). Basals for both subtests were when all items are passed at two consecutive levels and ceilings were when three failures (out of four possible) occur across adjacent levels. Raw scores, age equivalents, and SAS scores were obtained for these subtests. Non-verbal mental age was measured by averaging the two age-equivalent scores obtained from the subtests. SAS scores were calculated for each subtest ($M = 10$; $SD = 3$) and a composite SAS computed ($M = 100$, $SD = 16$) for each participant using tables in the manual.

*3.3.2 English and French Language Measures.*

To measure English and French language abilities and their change over time, three comparable subtests were administered in each language from the *Clinical Evaluation of Language Fundamentals-IV* (CELF-IV, Semel, Wiig, Secord, 2003) and l'*Évaluation Clinique des Notions Langagières Fondamentales* (CELF-IV CDN-FR, Wiig *et al.*, 2009*)* to the bilingual participant. These were used because they measured a range of language abilities and they were the same tasks used in the previous study of the bilingual participant. Only the English versions of the subtests were administered to the monolingual group. In the Concepts and Following Directions/Concepts et Exécution de Directives subtest, the participant was asked to follow a series of spoken directions of increasing length and complexity. In the Word Structure/Morphologie subtest, the participant was asked to complete sentences using the targeted grammatical structure. In the Recalling Sentences/Répétition de Phrases subtest, the participant was asked to repeat sentences of increasing length and complexity verbatim. Basals and ceilings for these subtests are described in Table 3. Raw and age-equivalent scores were calculated for each of these subtests.

**Table 3** Basals and Ceilings for CELF-IV and CELF-IV CDN-FR subtests.

| Subtest | French | English |
| --- | --- | --- |
| Recalling sentences/ Répétition de Phrases | No Basal: Start at Item 1<br>Ceiling: 5 consecutive incorrect items | Basal: correct score on 2 consecutive items<br>Ceiling: 4 consecutive incorrect items |
| Word Structure/ Morphologie | No basal or ceiling—administer all items | No basal or ceiling—administer all items |
| Concepts and Following Directions/Concepts et Exécutives de Directives | Basal: Correct score on 2 consecutive items<br>Ceiling: 7 consecutive incorrect items | Basal: Correct score on 2 consecutive items<br>Ceiling: 4 consecutive incorrect items |

*Notes*. CELF-IV = Clinical Evaluation of Language Fundamentals-IV (Semel, Wiig, Secord, 2003). CELF-IV CDR-FR = Évaluation Clinique des Notions Langagières Fondamentales (Wiig et al., 2009).

*3.3.3 English and French Reading Measures.*

The real word and nonsense word reading subtests from the *Woodcock Reading Mastery Tests – 3rd edition* (*WRMT-III*, Woodcock, 2011) and parallel subtests in the *Test de Rendement Individuel de Wechsler* (*WIAT-II FR*, Wechsler, 2005) were used to assess the bilingual participant's English and French word and non-word reading skills Again, these were used because they were the same tasks used in the previous study of the bilingual participant and they were comparable to the English tests. Only the WRMT-III was used with the monolingual group.

In the real word subtests (Word Identification subtest of the *WRMT-III and Lecture de mots subtest of the WIAT-II)*, the examiner pointed to a word on a page and asked the participant to read the word out loud. In the non-word reading subtests (Word Attack subtest of the WRMT-III and Décodage de Pseudo-mots subtest of the WIAT-II), the participant was asked to read nonsense words aloud. For both subtests, if the participant read correctly, they were given one point, and if the participant did not respond or responded incorrectly, they were awarded 0 points. The basal for the WRMT-III subtests was three consecutive correct items and the ceiling was four consecutive scores of 0. In the WIAT-II subtests, the bilingual participant began with item 1 and the ceiling was seven consecutive scores of 0. For each subtest, raw and age-equivalent scores were calculated.

### *3.3.4 Executive Function Measures*

Four EF tasks were administered: a Go/No-Go task and a Flanker task were used to measure inhibitory control; The Flexible Item Selection task (FIST) was used to measure cognitive flexibility; and the Backwards Digit Span task measured working memory. The Forward Digit Span task was also administered but was not used to measure EF because it was considered a short-term memory task rather than a working memory task. Three of the EF tasks (Go/No-Go, Flanker, and FIST) were developed by Jacques *et al.* (2001) and programmed in Eprime 2.0 with pictures downloaded from Pontifex's lab (Pontifex, Saliba, Raine, Picchietti, & Hillman, 2012; Voss et al., 2011). These tasks were administered using a touch-screen computer. All instructions were provided to the participants via the computer. The FIST task had previously been used in a study with young adults with DS (mean age of 15 years, 3 months) (Campbell, Landry, Russo, Flores, Jacques, & Burack, 2013). Both the FIST and the Flanker task have been used on typically developing children, ages 4 and above (Jacques, Rahbari, & Hughes, 2014, and Mohamed, 2015, respectively). Results from these studies were used as further comparisons to the performance of the bilingual participant.

**Inhibitory Control**

*Go/No-Go Task.*

In the Go/No-Go Task, the participant was shown a picture of a sun on a computer screen and then a picture of a moon (see Figure 1). The participant was instructed by the computer to press a blue button located on the track pad when they saw a sun ("go trials") but withhold their response when they saw a moon ("no-go trials"). The first block of trials (n=16) were practice trials; half of the trials consisted of suns. During practice, if a participant responded correctly when they saw a sun, the computer said "*Yes, that's right! Good job. When you see the sun, you touch the blue button*." If a participant did not respond or responded incorrectly when they saw a sun, the computer said "*Remember you have to touch the blue button when you see the sun*". Trial blocks 2 and 3 were test trials and no corrective feedback was provided. In block 2 (N=32), 75% of the pictures were suns and in block 3 (N=32), 25% of pictures were suns.

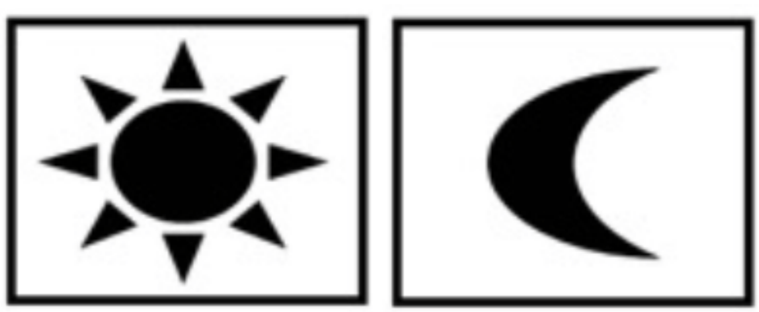


*Figure 1*. Sun and moon images from the Go/No-Go Task, Jacques & Zelazo (2001).

Scores from the first block of trials were not counted as they were used as practice. For the second and third blocks combined, three different measures were calculated: total correct for “go” and “no-go” trials and “false alarms”. For the “go trials”, a participant was awarded a score of 1 every time they pressed the button when they saw a sun. For the “no-go trials”, a participant was awarded of score of 1 every time they withheld from pressing the button when they saw a moon. There were 32 “go” and 32 “no-go” trials in total. The closer a score was to 32 on each of these trials, the better the performance. For the “false-alarm” scores, a participant was awarded a score of 1 for every time they pressed the button erroneously in the “no-go” trials. The closer a score is to 0, the better the “false alarm” performance.

*Flanker Task*

In the Flanker Task, the participant was shown a central stimulus of a fish and they must make the judgment whether the fish is pointing to the left or right. This fish was then “flanked by” four other fish, two on each side, that either faced the same direction as the middle fish (i.e., congruent), or in the opposite direction (i.e., incongruent) (see Figure 2). At the bottom of the touch-screen, there were two arrows, referred to by the computer as “buttons”, one pointing to the left and one pointing to the right. The participant was asked to press the “button” that pointed in the same direction the middle fish was facing.


*Figure 2*. Fish images from the Flanker Task, Jacques & Zelazo (2001).

They were given four practice trials for both congruent and incongruent trials, for a total of 8 practice trials, so they understood they must only pay attention to the center fish. For each practice trial, the computer would say, "*Show me which button you would press if the middle fish is pointing this way. Press it now!*" If the participant answered correctly, the computer said, "*Good work! That's right. If the middle fish is pointing this way, you would press this button*" and the correct button was highlighted. If the participant answered incorrectly, the computer said, "*Good try, but the middle fish is pointing this way so I'll choose this button*" and the correct button was highlighted. If the participant did not respond, the computer said, "*Oops, it's your turn. Touch the button that points the same way as the middle fish. Press it now*!" No additional practice trials were given, even if the participant answered incorrectly. The practice trials were followed by two blocks of 24 test trials where a participant was awarded one point every time they chose the button on the same side of the screen as the center fish faced. The exact same task was completed a second time, including practice trials, but this time with arrows pointing to the left or right instead of fish (see Figure 3).

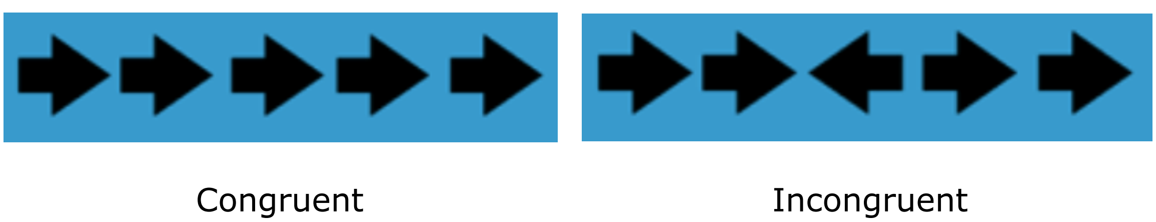



*Figure 3*. Arrow images from the Flanker Task, Jacques & Zelazo (2001).

Scores from the fish trials and the arrow trials were combined. Over the both, there were an equal number of congruent and incongruent trials (24 total of each). Inhibitory control was calculated in two ways; as the score on incongruent trials and as the difference in accuracy for trials with congruent and incongruent flankers. For the score on incongruent trials, a higher score represents greater inhibitory control. When measured by the difference between congruent and incongruent trials, a difference score closer to 0 represents greater inhibitory control because a participant is performing equally as well when there is conflicting information that they must inhibit to perform the task.

**Cognitive Flexibility**

*Flexible Item Selection Task (FIST)*

A FIST was used to measure cognitive flexibility. In the FIST, the participant was shown a computer screen with four pictures on the screen at a time that can match one another on 3 attributes: color, shape, or size.

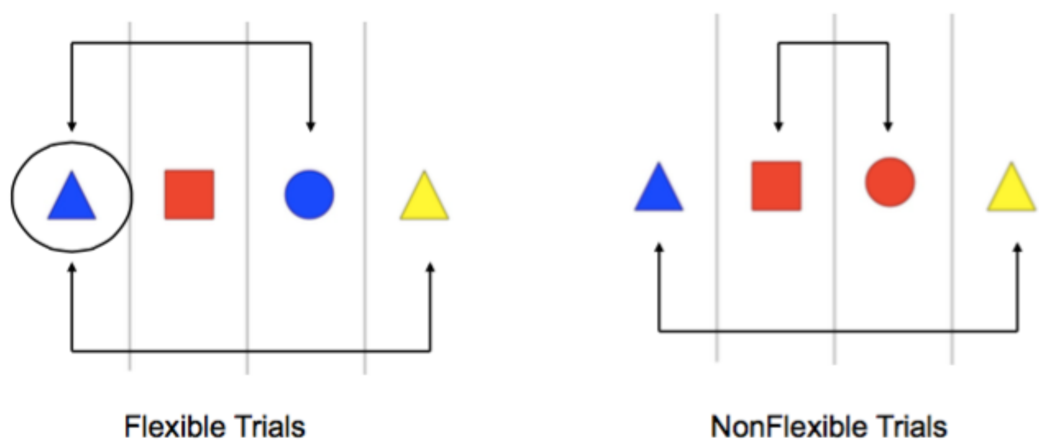



*Figure 4.* Flexible and Non-Flexible Trial Images from FIST Task, Jacques & Zelazo (2001).

In the FIST task, there were two demonstration trials followed by two practice trials, and then 18 test trials for scoring. For the first demonstration trial (a non-flexible trial), the following instructions were given by the computer and an image of a hand appeared on the screen to point to each picture as it was discussed: *"You and I are going to play a pick-some-pictures game together. I'm going to pick pictures first, just to show you how to do it, and then you'll pick some pictures. Look carefully. I'm going to pick 2 pictures that go together in one way. So I'm going to pick this picture here and this picture here. These two pictures go together in one way. Now I'm going to pick 2 pictures that go together but in another way. So I'm going to pick this picture here and this picture here. These two pictures go together but in another way. So I picked these two pictures here because they go together in one way and these two pictures here, because they go together but in another way.*" The same script was read for the second demonstration trial (a flexible trial). The first practice trial was a non-flexible trial and the second practice trial was a flexible trial. The following script was said by the computer at the beginning of the practice trials: "*Now it's your turn to pick pictures. Use one finger to touch one picture at a time. Make sure you hear the beep after each touch. Now, pick 2 pictures that go together in one way*." An image of a hand appeared underneath each picture as the participant pressed it, as well as a beep sounded. If the participant answered correctly, the computer said: "*That's right, these two pictures go together in one way*." If the participant answered incorrectly, the computer said: "*That was a good try, but these two pictures here go together in one way. Now, can you pick two pictures that go together but in another way?*" If the participant did not respond, the computer said: "*Remember, pick two pictures that go together in one way*." After the two practice trials, the test trials began and the computer said: "*Now you know how to play my game, so we can go a bit faster. So remember, when I show you the pictures, pick two pictures that go together in one way and then pick two that go together but in another way. Make sure when you are picking pictures to only touch one picture at a time and that you hear the beep after each touch.*

*Are you ready? Here we go!*" No additional feedback was given, even if the participant answered incorrectly.

On half of the test trials (cognitive flexibility trials; N = 9), one of the items was involved in both matched pairs, which required the participant to be flexible in which dimension they were matching on. For these "flexible trials", a participant was awarded a maximum score of 1 per trial when they matched two items correctly on one dimension and then matched one of these items to another item on a different matching dimension than the first. A participant was given a score of 0 if they matched two items correctly on the first selection but failed to match two items correctly on the second selection, or if they failed to match any two items correctly.

On the other half of trials (n = 9), the items did not overlap on matching dimensions (Figure 4). For these "non-flexible trials", a participant was awarded a maximum score of 1 per trial every time they matched two items on one dimension and then the other two remaining items on another dimension. In order to obtain a score of 1, they must match two items correctly on both the first selection and on the second selection. They were given a score of 0 if they failed to match two items on either the first or the second selection. The flexible and non-flexible trials were interspersed. Cognitive flexibility was measured by performance on the flexible trials for a possible total score of 9, therefore those trials in which the participant had to think of one picture in two ways. Non-flexible scores were also calculated for a possible total score of 9.

**Working Memory**

*Forward Digit Span and the Backwards Digit Span*

The Forward Digit Span and the Backwards Digit Span tasks of the *WISC-IV*

(Weschler, 2004) were administered to measure short-term and working auditory verbal memory respectively. While both tasks involve holding information in memory, the Backwards version requires a participant to hold that information in memory and then operate on it, which makes it more a “working” memory than simply an auditory verbal short-term memory task like the Forward version. In the Forward Digit Span task, the participant was read a series of digits and was asked to repeat them.  In the Backwards task, the participant was read a series of digits and was asked to repeat them back to the examiner in reverse order. The test trials began with a series that were two digits in length with two items of the same length before moving on to the next series. Each subsequent series added one more digit. If a participant responded incorrectly on any item, the sequence was repeated and they were provided with another opportunity to respond. They were awarded 1 point for every correctly recounted sequence, regardless if it was on the first reading or the repeat reading. The task ended when a participant failed both items at a given length. Raw and age-equivalent scores were calculated for both the Forward and Backwards tasks, using the *WISC-IV* scoring manual.

A summary of all measures used in the study is shown in Table 4.

**Table 4.** Measures of language, reading, and executive function administered in this study.

| | |
|---|---|
| *Non-verbal Mental Age* | *Stanford-Binet Intelligence Scale-IV* (Roid, 2003); Subtests: Bead Memory and Pattern Analysis |
| *Auditory Memory* | Forwards Digit Span: *Weschler Intelligence Scale for Children V* (WISC-IV, Weschler, 2004) |
| *English Language* | *Clinical Evaluation of Language Fundamentals-IV* (CELF-IV, Semel, Wiig, Secord, 2003): Subtests: Concepts and Following Directions, Word Structure, and Recalling Sentences |
| *English Reading* | *Woodcock Reading Mastery Test III* (WRMT-III, Woodcock, 2011): Subtests: Real word and Nonsense word |
| *French Language* | *Évaluation clinique des notions langagières fondamentales, version for Francophone Canadians* (CELF-IV CDN-F, Wiig et al., 2009): Subtests: Concepts et Exécution de Directives, Répétition de Phrases, and Morphologie |
| *French Reading* | *Test de Rendement Individual de Wechsler* (*WIAT-II FR*, Wechsler, 2005): Subtests: Lecture de Mots and and Décodage de Pseudo-mots |
| *Cognitive Flexibility* | The Flexible Item Selection Task (FIST, Jacques & Zelazo, 2001) |
| *Inhibitory Control* | a) Go/No Go Paradigm (GNG, Jacques & Zelazo, 2001), b) Flanker (Flanker, Jacques & Zelazo, 2001) |
| *Working Memory* | Backwards Digit Span: *Weschler Intelligence Scale for Children-V* (WISC-IV, Weschler, 2004) |

### 3.4 Procedure

The bilingual participant was tested at two separate time periods. In both time periods, he was tested in each language on different days. This was to minimize effects of fatigue and reduce the occurrence of language mixing. The first time (T1), after he had completed 5 years of FI, his French language and reading skills were tested first, followed by his English language and reading skills. The SB-IV, WISC-IV, and EF tasks were not administered at the first testing. At the second test (T2) period, after the bilingual participant had completed 7 years of FI. On the first day of T2, the participant was administered the subtests for French language from the CELF-IV CDN-FR (Répétition de Phrases, Morphologie, and Concepts et Execution de Directions) and French reading from the WIAT-II (Lecture de Mots and and Décodage de Pseudo-mots), in that order. The second day, the participant was administered the Stanford-Binet Intelligence Scale-IV subtests (Bead memory and Pattern Analysis), the Weschler Intelligence Scale for Children-IV subtests (Forward and Backward Digit Span), the CELF-IV (Concepts and Following Directions, Recalling Sentences, and Word Structure), the EF tasks (Go-No Go, FIST, and Flanker), then the Woodcock Reading Mastery Test III subtests (Real Word and Nonsense Word), in that order.

The monolingual group completed all testing on the same day. The English reading, language, short-term memory, and EF tasks were presented to the monolingual participants in the same order as for the bilingual participant. This order was predetermined in order to keep the participants interested, to separate tasks that are similar, and to ensure that order effects were similar for all participants. Total testing time was approximately 90 minutes per testing session, including time for breaks.

## 3.5 Data Analyses

### *3.5.1 Longitudinal analysis*

The bilingual participant's English and French language and reading age-equivalent scores were plotted for T1 to T2. Change over time and variation across languages were assessed through visual inspection.

### *3.5.2 Comparative analysis*

To compare the English language and reading skills of the bilingual participant to the group of monolinguals, raw scores and age-equivalents were used. For these tasks, a mean score was calculated for the group of monolingual participants, as well as the standard deviation of their scores,. English language and reading and EF raw scores of the bilingual participant were compared to the group of monolinguals using the statistical procedure of Groen et al. (2006), which employed the use of the program SINGLIMS.EXE (Crawford & Garthwaite, 2002). This program used a modified t-test, which allowed a comparison of the bilingual participant's score to the mean scores of the monolingual comparison group. It served as a significance test to determine whether the null hypothesis could be rejected if the bilingual participant's score is different than the comparison group. This analysis included determining a point estimate, which extrapolates from the data of the monolingual comparison group to the larger monolingual population with DS and provides a percentage of the hypothetical monolingual population with DS that would be expected to perform below the bilingual participant's score.

# CHAPTER 4: RESULTS

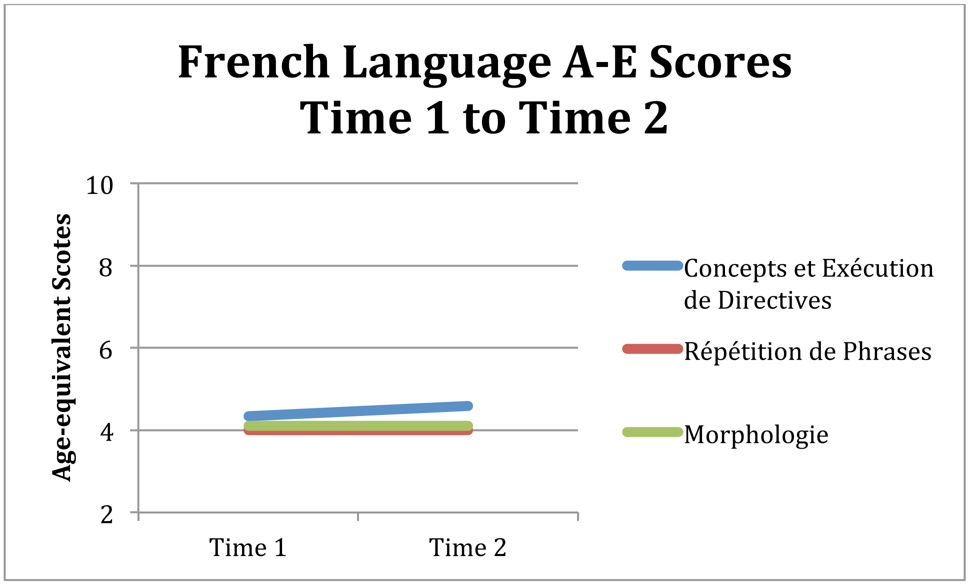
## 4.1 Bilingual Participant: Longitudinal Analysis

### *4.1.1 Language Results*

Age-equivalent scores for the bilingual participant's French and English language skills at T1 and T2 are shown in Figures 5 a and b respectively.

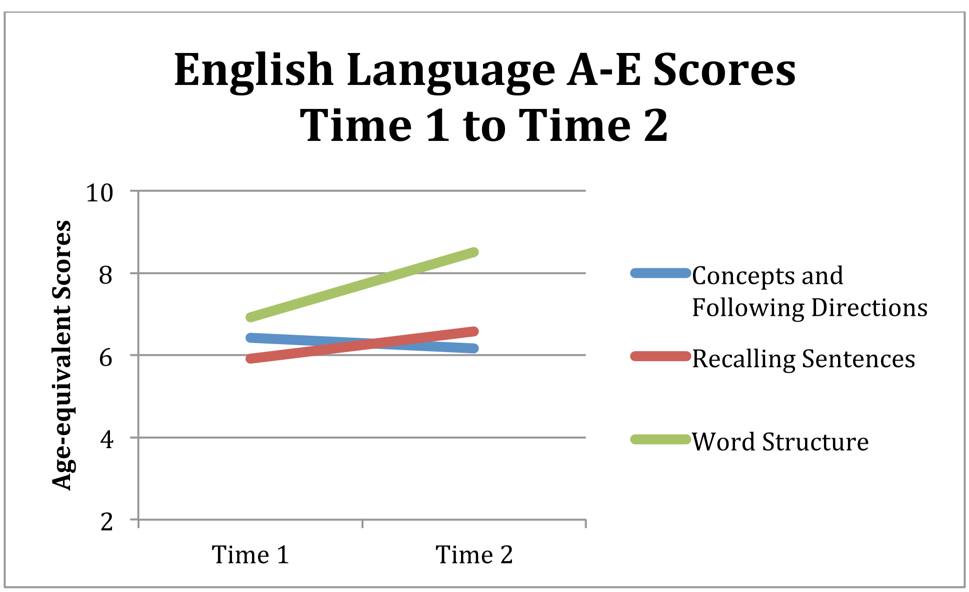
As shown in Figure 5a, the bilingual participant's French language skills showed a slight gain (4;4 to 4;7) for one subtest only, Concepts et Execution de Directives. Age-equivalent scores for the Repetition de Phrases and the Morphologie subtests were at <4;0 at both T1 and T2. Figure 5b shows that the participant's English language skills are higher than his French language skills for all three measures. Over time, a slight decrease in performance for English Concepts and Following Directions (6;5 to 6;2) was observed, but increases of eight months for Recalling Sentences (5;11 to 6;7) and over a year and a half for Word Structure (6;11 to 8;6) were observed.

*Figure 5a*. Bilingual Participant's French Language Development from T1 to T2, Age-equivalent scores.




*Notes*. Concepts et Exécution de Directives, Répétition de Phrases, and Morphologie are subtests from the CELF-IV CDR-FR (Wiig et al., 2009). Both age-equivalent scores for Répétition de Phrases and Morphologie at time 1 and time 2 were <4;0 but they were plotted in this graph as 4;0.

*Figure 5b*. Bilingual Participant's English Language Development from T1 to T2, Age-equivalent scores.

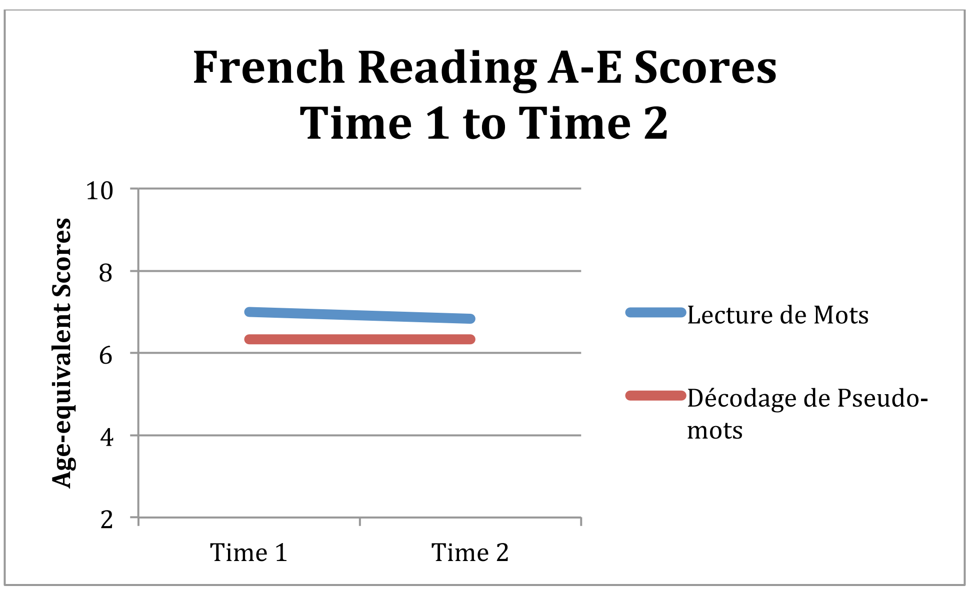



*Notes.* Concepts and Following Directions, Recalling Sentences, and Word Structure are subtests from the CELF-IV (Semel, Wiig, Secord, 2003).

*4.1.2 Reading Results*

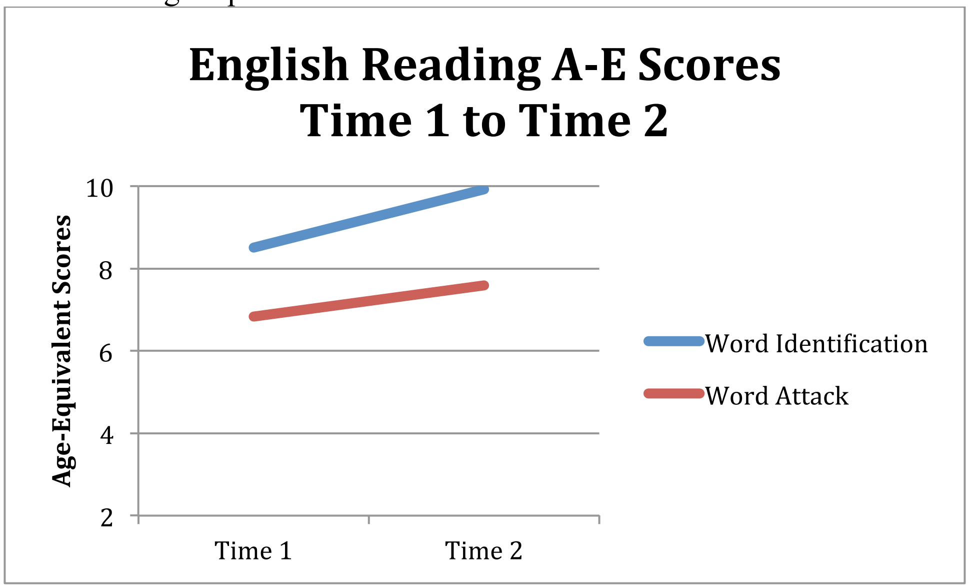
Age-equivalent reading scores in Times 1 and 2 are shown in Figures 6a (French) and 6b (English). From time 1 to time 2, the bilingual participant's French word-reading (e.g. 'fête', 'pont') abilities decreased by an age-equivalency of four-months and his ability to read French non-words (e.g. 'reux', 'til') remained the same at 6;4. His English reading abilities were at a higher level than his French and showed more improvement, with an age-equivalency gain of a year and 5 months for his English word-reading ability (e.g. 'yes', 'milk') and a gain of 9 months for his English non-word reading ability (e.g. 'op', 'bim').

*Figure 6a*. Bilingual Participant's French Reading Development from T1 to T2, Age-equivalent scores.




*Notes.* Lecture de Mots and Décodage de Pseudo-mots are subtests from the *WIAT-II FR*, Wechsler, 2005).

**Figure 6b** Bilingual Participant's English Reading Development from T1 to T2, Age-equivalent scores.




*Notes.* Word Identification and Word Attack are subtests from the *WRMT-III* (Woodcock, 2011).

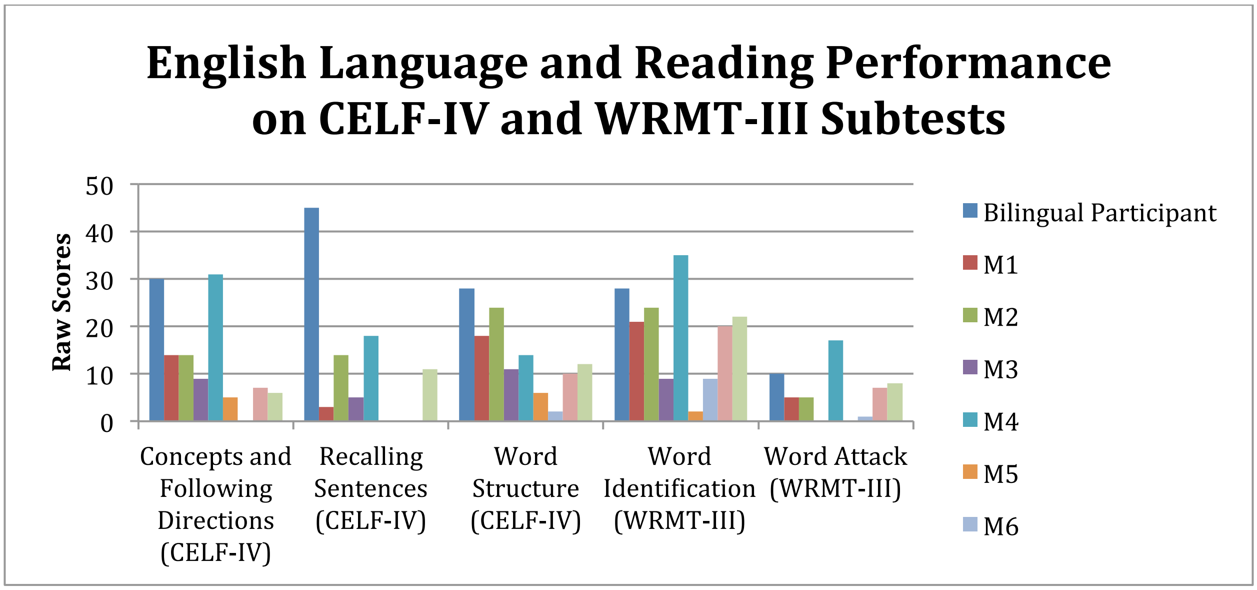
## 4.2 Bilingual-monolingual Comparisons

### *4.2.1 English Language Results*

Figures 7a and 7b present the raw and age-equivalent scores respectively for each English language and reading measure for the bilingual participant and each monolingual participant. These figures show the bilingual participant performed higher than all but one of the monolingual participants on every measure.

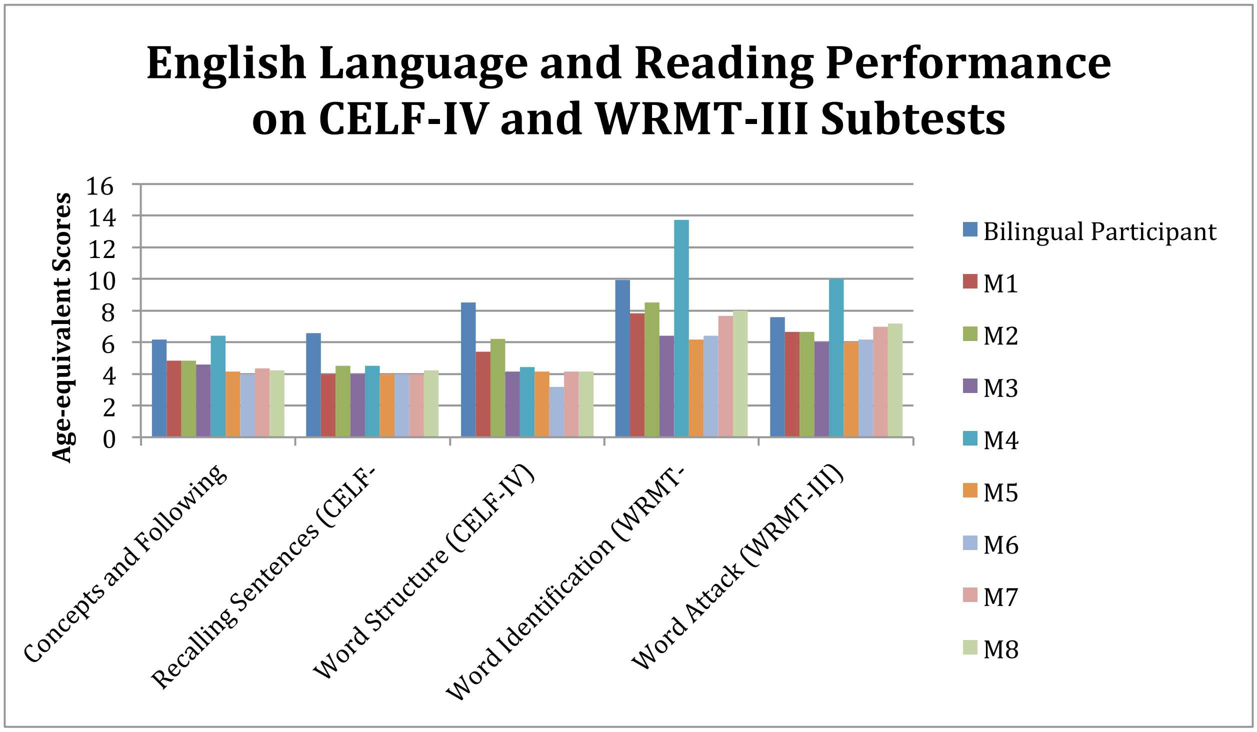
As can be seen, the bilingual participant's English language scores, while generally higher than those of the monolinguals, was significantly higher than the monolingual group on only one language subtest (Recalling Sentences), although his scores approached significance on the other two language subtests. For all three of the language subtests, the point estimates ranged from 95.24 to 99.94, meaning that less than 5% of the monolingual population with DS would be expected to perform better than the bilingual participant on these language subtests, hypothetically. The point estimates for the bilingual participant's reading scores were not as high, with just over 80% of the hypothetical monolingual population with DS expected to score below on word-reading ability and just over 75% expected to score below on non-word reading ability.

*Figure 7a* Comparison of English Language and Reading on CELF-IV and WRMT-III Subtests between bilingual participant and monolingual participants, Raw scores.




*Notes.* CELF-IV= Clinical Evaluation of Language Fundamentals-IV. WRMT-III= Woodcock Reading Mastery Tests – 3rd edition.

*Figure 7b* Comparison of English Language and Reading on CELF-IV and WRMT-III Subtests between bilingual participant and monolingual participants, Age-equivalent scores.




*Notes.* CELF-IV= Clinical Evaluation of Language Fundamentals-IV. WRMT-III= Woodcock Reading Mastery Tests – 3rd edition.

**Table 5** Raw scores on English language and reading tasks for bilingual participant at T2, compared with that of a group of monolingual participants with DS (means, SD), matched to bilingual participant on chronological age and mother's education level.

| Measure (max score) | Bilingual Participant | DS (*n=8*) *M* (*SD*) | Point estimate[1] (95% CI) | *t* value | *p* value (*two-tailed*) |
|---|---|---|---|---|---|
| English Language Subtests from the CELF-IV | | | | | |
| Concepts and Following Directions (54) | 30 | 10.75 (9.41) | 95.24 (77.94-99.95) | 1.93 | 0.095 |
| Recalling Sentences (96) | 45 | 6.38 (7.07) | 99.94 (99.51-100.00) | 5.15*** | 0.001 |
| Word Structure (32) | 28 | 12.13 (6.81) | 96.80 (82.46-99.99) | 2.20 | 0.064 |
| English Reading Subtests from the WRMT-III | | | | | |
| Word Identification (46) | 28 | 17.75(10.50) | 80.60 (53.94-96.48) | 0.92 | 0.388 |
| Word Attack (26) | 10 | 5.38 (5.63) | 76.78 (49.56-94.64) | 0.77 | 0.464 |

*Notes.* CI= confidence interval; M = mean; SD = standard deviation. CELF-IV= *Clinical Evaluation of Language Fundamentals-IV*. WRMT-III= *Woodcock Reading Mastery Tests – 3rd edition*. [1]Percentage of the English population with DS aged 12-17 years with a maternal education of high school or greater estimated to perform below bilingual participant's score.

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

### *4.2.2 Executive Function Results*

**Inhibitory Control**

*Go/No-Go Task*

In Table 6, the individual data for the Go/No-Go Task is presented. For the Go/No-Go task, inhibitory control is theoretically measured by the no-go trials (the trials in which a participant had to withhold from pressing the button when they saw a moon). Scores obtained on the no-go trials (Table 6) suggest that the participants did inhibit their response when they saw the moon, possibly indicative of increased inhibitory control. However, when the go-trial scores are taken into consideration, it appears that the participants are not pressing the button when they see the sun either. Taken together these scores seem to be a reflection of their inability to understand the task in general. The false alarm score was therefore considered a better measure of inhibitory control because it accounts for both the participant's ability to respond and not respond appropriately. The closer the false alarm score was to 0, the greater the participant's inhibitory control. Although the false alarm score was thought to be a better measure of inhibitory control than the no-go trials, the scores should be interpreted cautiously as the participants appeared to not understand this task in general.

**Table 6** Go/No-Go Task raw scores for the bilingual participant and monolingual participants.

| Go/No-Go Task | Go Trials (total=32) | No-Go Trials (total=32) | False Alarm (total=32) |
|---|---|---|---|
| Bilingual Participant | 9 | 31 | 1 |
| M1 | 5 | 29 | 3 |
| M2 | 12 | 28 | 4 |
| M3 | 19 | 28 | 4 |
| M4 | 13 | 32 | 0 |
| M5 | 11 | 24 | 8 |
| M6 | 4 | 31 | 1 |
| M7 | 13 | 30 | 2 |
| M8 | 18 | 12 | 20 |
| Results | Mean: 11.8<br>SD: 5.36 | Mean: 26.8<br>SD: 6.43 | Mean: 5.25<br>SD: 6.43 |

*Notes.*SD = standard deviation

Table 11 shows the statistical analyses of how the bilingual participant scored compared to the means of the monolingual group on all EF measures. As can be seen, the bilingual participant performed comparatively to the monolingual participants on the False Alarm trials, with a score falling within one standard deviation of the mean of the monolingual participants. The t-test did not indicate a difference for inhibitory control on the Go/No-Go task, with a point estimate of 27.65% of the monolingual population with DS estimated to perform better than the bilingual participant

*Flanker Task*

For the Flanker task, there were two ways inhibitory control was calculated. To compare the bilingual participant to the monolingual comparison group, the difference between scores on congruent trials and incongruent trials was used. Both types of trials were taken into consideration because the congruent trial scores are important to see if the participant understood the task, and the incongruent trial scores are important to see if the participant was successful at inhibiting conflicting information. In theory, incongruent trials should be more difficult to perform accurately because they include conflicting information in which the participant must inhibit to answer correctly. As Table 7 shows, this is the case for all the participants—they all scored better on the congruent than incongruent trials. If they had performed as well on the incongruent trials as on the congruent trials, increased inhibitory control would have been indicated. However this was not the case for any of the participants. As Table 7 shows, the bilingual participant's score fell in the middle of the scores of the comparison group. The t-test performed on this measure, as shown in Table 11, was not significant, although an estimated 82.67% of the monolingual population with DS would perform better than the bilingual participant on this task.

**Table 7**. Flanker Task raw scores for the bilingual participant and monolingual participants.

| Flanker Task | Congruent Trials (total=24) | Incongruent Trials (total=24) | Difference between Congruent and Incongruent Trials (total=24) |
|---|---|---|---|
| Bilingual Participant | 22 | 14 | 8 |
| M1 | 23 | 11 | 12 |
| M2 | 24 | 21 | 3 |
| M3 | 20 | 6 | 14 |
| M4 | 24 | 24 | 0 |
| M5 | 22 | 19 | 3 |
| M6 | 24 | 14 | 10 |
| M7 | 24 | 12 | 12 |
| M8 | 24 | 24 | 0 |
| Results | Mean: 23.13<br>SD: 1.46 | Mean: 16.38<br>SD: 6.61 | Mean: 6.75<br>SD: 5.82 |

*Notes.*SD = standard deviation

This same Flanker task was administered to a group of 29 typically developing children, mean age of 61.93 months (SD = 8.43), in an unpublished honours thesis (Mohamed, 2015). In this study, Mohamed used scores on incongruent trials only to measure inhibitory control. The children in her study were of a different chronological age but a similar mental age to the bilingual participant. The bilingual participant obtained a score that wasgreater than two standard deviations below the mean of the typically developing children (Table 8).  The point estimate showed that only 2.58% of typically developing English children aged approximately 5 years would be expected to perform below the bilingual participant's score. The monolingual group with DS also scored more poorly than the TD children, with a mean score falling more than 1 SD below the mean for the TD group.

**Table 8** Inhibitory control performance of bilingual participant on Flanker task at T2, compared with that of participants with Down syndrome, and of typically developing monolingual English children, matched by chronological age.

| Flanker Task (max score) | Bilingual Participant | DS (*n*=8) *M (SD)* | Point estimate[1] (95% CI) | TD (*n*=29) *M (SD)* | Point estimate[2] (95% CI) |
|---|---|---|---|---|---|
| Incongruent Trials (24) | 14 | 16.38 (6.61) | 37.21 | 20.62 (3.2) | 2.58 |
| Difference between Incongruent Trials and Congruent Trials (24) | 8 | 6.75 (5.82) | 57.74 | – | – |

*Notes.* CI = confidence interval; M = mean; SD = standard deviation.[1]Percentage of the English population with DS ages 12-17 years estimated to perform below bilingual participant's score. [2]Percentage of the typically developing English population aged approximately 5 years estimated to perform below bilingual participant's score.

**Cognitive Flexibility**

Table 9 provides individual data for the non-flexible and flexible trials. As it shows, there was a floor effect for the flexible trials, none of the participants were able to accurately match on the second selection. In other words, none of them were successful in thinking of one picture in two ways. The score of 1 achieved by one of the monolingual participants can be assumed to be by chance. Given there was no variability in performance on this task, a statistical analysis was not completed. Indeed, the participants did not appear to understand the task and selected all four items presented, in varying orders, throughout the task. Therefore, these results are not considered a valid reflection of cognitive flexibility.

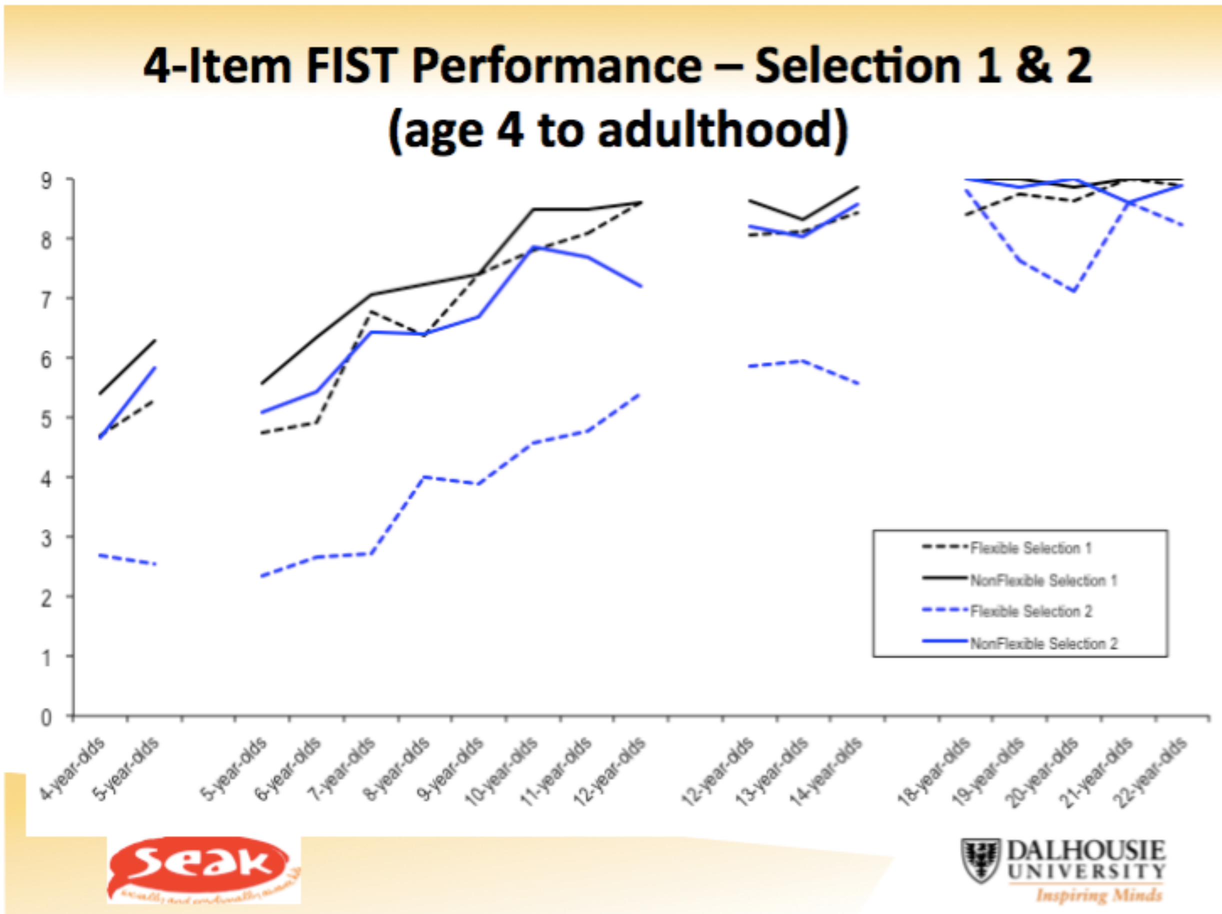
**Table 9** Flexible Item Selection Task raw scores for the bilingual participant and monolingual participants.

| Flexible Item Selection Task | Non-Flexible Trials (total=9) | Flexible Trials (total=9) |
|---|---|---|
| Bilingual Participant | 5 | 0 |
| M1 | 8 | 0 |
| M2 | 7 | 0 |
| M3 | 4 | 0 |
| M4 | 9 | 0 |
| M5 | 3 | 1 |
| M6 | 0 | 0 |
| M7 | 6 | 0 |
| M8 | 5 | 0 |
| Results | Mean: 5.25<br>SD: 2.92 | Statistical analysis not performed |

*Notes.* SD = standard deviation

This same Flexible Item Selection Task was completed by typically developing participants, ranging in age from 4 years to adults, in a study by Jacques, Rahbari, & Hughes (2014). Change in scores on the FIST with age are shown in Figure 8Typically developing participants as young as 4 years old were on average able to correctly identify two different matched items in two different trials and this increased to an average of 9 different trials for the adults.

*Figure 8.* Flexible Item Selection Task Performance of typically developing participants, ranging in age from 4 to adulthood.




*Notes.* Jacques, S., Rahbari, N., & Hughes, J. (2014, May). Cognitive Flexibility and academic performance; Concurrent and longitudinal relations, and variables that may limit or potentiate relations. In G. Podjarny (Chair), *Current issues in cognitive flexibility development during childhood*. Paper symposium presented at Development 2014; A Canadian Conference on Developmental Psychology, Ottawa, Canada.

## Working Memory

### *Backwards Digit Span*

Table 10 provides individual data for the Forwards and Backwards Digit Span tasks. A statistical analysis of the measure of working memory (the Backwards Digit

Span task) was not completed because only 3 monolinguals and the bilingual participant could do this task at all (the others did not respond correctly to any item). Nonetheless, it is interesting to note that the bilingual participant performed better than all but two of the monolingual participants on this task. Although not considered a measure of working memory, a statistical analysis was completed for the Forward Digit Span task and results are shown in Table 10. The point estimate for this task showed that just over half (57.88%) of the monolingual population with DS would be expected to perform better that the bilingual participant.

**Table 10** Digit Span Task raw scores for the bilingual participant and monolingual participants.

| Digit Span Tasks | Forward (Total=16) | Backwards (Total=16) |
|---|---|---|
| Bilingual Participant | 5 | 4 |
| M1 | 4 | 0 |
| M2 | 5 | 0 |
| M3 | 4 | 4 |
| M4 | 7 | 7 |
| M5 | 3 | 0 |
| M6 | 2 | 0 |
| M7 | 6 | 0 |
| M8 | 6 | 5 |
| Results | Mean: 4.63<br>SD: 1.69 | Mean: 2<br>SD: 2.88 |

*Notes.* CI = confidence interval. [1]Percentage of the English population with DS ages 12-17 years estimated to perform below bilingual participant's score.; M = mean; SD = standard deviation.

**Table 11** Performance of bilingual participant on measures of executive functioning and Forward Digit Span, compared with that of participants with Down syndrome, matched on chronological age.

| Measures of EF (task, max score) | Bilingual Participant | DS (n=8) M (SD) | Point estimate1 (95% CI) | t value | p value (two-tailed) |
|---|---|---|---|---|---|
| Inhibitory Control | | | | | |
| Go-No Go Task (False Alarm, 24) | 1 | 5.25 (6.43) | 27.65 (7.87-55.1) | -0.623 | 0.553 |
| Flanker (Difference, 24) | 8 | 6.75 (5.82) | 57.74 (31.06-81.84) | 0.202 | 0.845 |
| Flanker (Incongruent, 24) | 14 | 16.38 (6.61) | 37.21 (14.33-64.39) | -0.339 | 0.744 |
| Cognitive Flexibility | | | | | |
| Flexible Item Selection Task (9) | (statistical analysis was not performed due to floor effect) | | | | |
| Working Memory | | | | | |
| Backwards Digit Span (16) | (statistical analysis was not performed due to floor effect) | | | | |
| Forward Digit Span (16) | 5 | 4.63 (1.69) | 57.88 (31.19-81.95) | 0.206 | 0.842 |

*Notes*. CI = confidence interval. [1]Percentage of the English population with DS ages 12-17 years estimated to perform below bilingual participant's score; M = mean; SD = standard deviation.

# CHAPTER 5: DISCUSSION

## 5.1 Bilingual Participant Longitudinal Outcomes

This is the first study that demonstrates the longitudinal success a person with DS can have in an FI program. The previous study of this bilingual participant (Hodder *et al.*, 2014) demonstrated his success for a single point in time but the present data shows how his language and reading skills have changed as he completed 2 additional years of FI. The data from time 2 of this study shows that the bilingual participant has developed French skills through participating in an FI program and that the language and reading measures used in this study were able to reflect this: not only is he becoming bilingual but he is also becoming biliterate. Despite achieving the lowest A-E scores for the Morphologie and the Répétition de Phrases subtests, the raw scores reflect a notable degree of French language achievement has been developed and maintained. The time 2 data shows that his English skills have continued to improve since time 1; he was performing above the age-equivalent language level of a 6 year-old and reading level of a 7 year-old. Although similar improvement was not noted in his French skills, and his French skills are not as good as his English skills based on the age-equivalent scores, he is developing language and reading skills in both languages nonetheless.

A possible reason for the lack of improvement in his French skills over the two year period studied is that is he has plateaued in his language abilities. But this does not appear to be true because he continues to improve in his English skills, despite being schooled in French.  A question is raised then why aren't his French skills developing? One possibility is that something has changed in his schooling. At time 2 of testing, his mother reported he had fewer classes instructed in French whereas at time 1 of the testing, every class was instructed in French with the exception of a one-hour English class, twice a week. This reported decrease in French language instruction is consistent with the structure of the New Brunswick FI program, according to the Government of New Brunswick (2013). It is possible the reduced French instruction in the classroom led to the lack of progress observed from time 1 to time 2, despite two additional years of FI. Another factor in his acquisition of French skills may be the structure of the New Brunswick program in that it begins in 3rd grade as opposed to Kindergarten like many other FI programs. Perhaps the bilingual participant would have achieved a higher degree of proficiency in French if he started FI in Kindergarten, when most early FI programs begin. A comparison of outcomes for both types of early FI programs may be warranted in future studies. It is also possible that the he tasks employed in this study were unable to capture the participant's progress. Expressive tasks, such as language samples, may be useful in future studies to better capture the French proficiency of participants. Nonetheless, his French language and reading abilities still represent a notable degree of bilingualism, which can be assumed to be superior to the monolingual comparison group's level of French skills but not superior to TD children in FI. TD children in FI typically develop 'native-like' receptive school-based French language skills by 11 years of age and by graduation, they achieve a high level of proficiency in the French writing and oral skills and writings (Lazaruk, 2007). Based on the TD research, at least the bilingual participant's receptive French language skills may have been expected to be higher by this amount of time spent in FI. However language learning difficulties are well documented in the research on children with DS (Chapman, 2003; Chapman & Kay-Raining Bird, 2011). This might explain his lower language levels compared to age-matched peers with similar input. Regardless, the bilingual participant's success in becoming bilingual through participating in FI supports the placement of students with DS in these programs.

### 5.2 Bilingual - Monolingual Comparisons

The second question addressed in this study was how the English language and reading skills of the bilingual student with DS compared to those of a monolingual group with DS, matched on chronological age. Although the bilingual participant was of a similar chronological age to the group, and his NVMA was not better than group's, his English language skills were better. On all language and literacy subtests, he outperformed every monolingual in the comparison group except for one. The one monolingual participant that scored better than the bilingual participant on almost all measures was the oldest participant in both chronological age (17;1) and in NVMA (7;11). Although it was hypothesized that the bilingual participant would score comparatively on measures of English language and reading, this was not the case. This is interesting, although not unique as better academic performances have been documented in research on TD children in FI (Lambert *et al.*, 1993). A possible reason for this is learning a second language may allow one to think about language differently or more systematically than would a monolingual and as a result, use these abilities to learn language more rapidly or more efficiently. Learning a second language allows one to analyze their first language differently while they draw comparisons and identify differences between the two. As a person learns a second language, they are constantly linking new vocabulary in this second language to vocabulary in their first language, and vice versa. It is possible that expanding one's language skills to two languages results in greater language abilities in general, including greater language abilities in one's first language. Alternatively, perhaps the English language skills of the bilingual participant would be better than his peers whether he was learning a second language or not. That is, perhaps his language learning capacity is higher than the most people with DS his age. This seems unlikely however, because, although his English language skills are better than the comparison group's, his NVMA and SAS are not. In the typical profile of DS, non-verbal abilities, as measured by the NVMA and SAS in this study, are better or at least on par with verbal abilities (Chapman *et al.*, 1991). It is possible that the bilingual participant may be an outlier in that he presents differently than the usual profile of DS, or it is possible that becoming bilingual helped him learn language better.

Not only do the results of this study show this bilingual participant is developing English skills as successfully and sometimes better than his peers, he is also developing considerable skills in a second language through a French Immersion program. These findings are evidence against excluding children with DS from FI programs because of fears that learning a second language will negatively affect their academic success or will hinder their native language growth.

With regards to EF, this study did not find any evidence that a bilingual advantage exists for individuals with DS after 7 years of French Immersion starting in third grade. None of the EF measures were successful in reflecting a significant difference between the bilingual participant and the monolingual comparison group. Although the inhibitory control and working memory tasks were not hypothesized to be performed better by the bilingual participant, he was expected to perform better on the cognitive flexibility task, which was not the result. Perhaps this lack of difference was due to the EF measures themselves as many of the participants had difficulty understanding the tasks, possibly related to their language difficulties typically seen in individuals with DS, which resulted in floor effects. But in both Mohamed (2015) and Jacques *et al.*'s (2014) studies, the younger children who were presumably of lower NVMA than the participants in the present study could do the tasks, therefore this claim is not likely.

In addition to the language used in the explanation of these tasks, there were a number of other challenges with the administration of these EF tasks to the participants. Some of the participants had difficulty with the motor component of pressing the touch screen button accurately, which impacted response rates when the trial ended before the participant was able to touch the right location on the screen for his or her selection. Another challenge was that some of the participants failed the practice trials and therefore did not perform well on the test trials because they did not understand the task. The program (Jacques & Zelazo, 2001) used for the EF tasks includes adaptations for children with disabilities and these should be used in future studies with such populations. The adaptations include the researcher touching the screen for the participant based on verbal responses, to reduce motor constraints, and the researcher providing additional instructions and practice if a child fails the practice trials. Overall testing fatigue may have been a factor as well, as the EF tasks were presented near the end of the testing session.

Another possibility is that the lack of difference was related to the impact of DS on EF abilities. As other research has shown (Lanfranchi *et al.*, 2010; Rowe *et al.*, 2006), EF is an area in which children with DS have dFIcits. As expected, the bilingual participant and the monolingual comparison group showed low levels of EF compared to the TD group on one measure of inhibitory control and the measure of cognitive flexibility. Despite there seeming to be evidence for EF advantages in TD bilingual children (Chan, 2005; Goetz, 2000; Adesope *et al*, 2010), it is possible that the EF dFIcits in children with DS are too severe that they may not allow them to evidence these same advantages. Although it was not expected for the bilingual participant in the present study to perform as well as TD children on the EF tasks, the hypothesis that he would perform better than the monolingual group with DS seemed reasonable. However the bilingual participant did not perform better than the monolinguals on any of the EF tasks. It is also possible that a bilingual advantage was not found in this study because there is not a bilingual advantage for EF, in TD children or those with DS, at all. For a long time, it was accepted that these bilingual advantages existed. More recently however, there has been some criticism on the research in this area (de Bruin, *et al.*, 2015; Paap, *et al.*, 2015; Hilchey *et al.*, 2011). Studies have sought to pinpoint exactly which types of EF are advanced in bilinguals, with inconsistent success. In Nicolay *et al*.'s (2013) study for example, an advantage was found in TD sequential bilingual children after 3-4 years in FI for cognitive flexibility but not for inhibitory control. Given those results, if the children in this study had have been TD, they may have been expected to have increased cognitive flexibility, but not increased inhibitory control, after FI exposure for 7 years. The period of exposure to a second language brings up another question. If a bilingual advantage does in fact exist, then what period of exposure or degree of bilingualism is necessary for the advantage to appear? This question has also been researched with inconsistent success. Perhaps the bilingual participant in this study had not yet attained a level of bilingualism for his EF skills to be advanced. Future research should continue to investigate the possibility of the EF bilingual advantage, the required degree of bilingualism required for it to appear, and the measures to detect it, in multiple populations.

**5.3 Limitations**

There were a number of limitations to this study. Firstly, the present study is a single subject case study. Given the large variability of the DS phenotype, information gathered from one bilingual participant participating in FI makes it difficult to draw definitive conclusions about others. This is a preliminary study and future studies should look at increasing the number of participants to capture the variability of language and reading skills in children with DS. This is difficult to accomplish as students with DS often have limited or no access to FI programs. A strength of this study is that a comparison group was collected to help interpret the performance of the bilingual participant. Although the size of the monolingual sample group is small and therefore limited in its ability to estimate the larger population of monolinguals with DS, it is comparable in size to other comparison groups in similar studies in this field (Bourgoyne, K., Duff, F., Nielsen, D., Ulicheva, A., & Snowling, M., 2016). Another limitation is that older versions of the Standford-Binet and the WISC were administered. The SB-IV was used because the two subtests used in this study are not included in the SB-V. New norms in the SB-V may place the participants differently in terms of intellectual disability. The WISC-IV was used because it allows for the Forwards and Backwards Digit Spans to be scored separately. In the analyses, raw scores and age-equivalent scores were used, instead of scaled scores, which do not take variability into account. They were used because scaled scores for these tasks could not be calculated. Another limitation of the tasks extends from the difficulty in measuring executive functioning. While the EF tasks used in this study have been successfully trialed with typically developing children and adults with DS, the language used in the explanation of the tasks appeared to be too complex for our bilingual and monolingual participants. This was most clearly demonstrated on the FIST task, where the flexible trials resulted in a floor effect and the non-flexible trials appeared to be misunderstood by the participants as well. Identifying appropriate tasks to test inhibitory control, working memory, and cognitive flexibility continues to be a challenge in the research on EF, but hopefully the results of this study may be of useful contribution to the creation or modification of such tasks.

# CHAPTER 6: CONCLUSION

Results of the current study support the findings of other studies of bilingualism in DS (Kay-Raining Bird *et al*., 2005; Edgin *et al*., 2011; Bourgoygne *et al.*, 2016; Feltmate *et al.*, 2008) that individuals with DS can and do become bilingual, with no detriment to their first language, and extends the findings to bilingual acquisition in an FI context. It also provides evidence of biliteracy acquisition, as one element of biliteracy is word-reading abilities, through the participation in FI. The EF tasks used in this study were unsuccessful at supporting the hypothesis that EF skills are advanced in bilingual individuals with DS, as they may be in typically developing bilingual children, albeit no disadvantage was identified in the results either. Regardless of whether there are cognitive advantages to speaking more than one language or not, there are a multitude of other advantages to bilingualism including but not limited to increased social interactions, links to cultural identity in certain geographical areas, and employment opportunities. While recognizing the limitations of this study, we hope this research is useful to educational providers, parents of children with DS, and other researchers in this field with regards to the inclusion of children with DS in second-language programs such as FI.

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