The Linguistic and Cognitive Effects of Bilingualism on Children with Autism Spectrum Disorders

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For my daughter,

my biggest achievement and the love of my life.

Table of Contents

ABSTRACT

Some professionals advise parents of bilingual children with Autism Spectrum Disorders (ASD) to talk to their child using only one language to simplify the input these children receive (Kay-Raining Bird, Lamond, & Holden, 2012; Kremer-Sadlik, 2005). This advice stems from the belief that bilingualism is challenging and may be harmful for language acquisition in children with this neurodevelopmental disorder (Kremer-Sadlik, 2005; Yu, 2013). Although research concerning the language development of bilingual children with ASD is scarce, the available evidence does not support this claim. Instead, findings suggest that bilingual children with ASD do not present additional language delays relative to their monolingual peers with ASD (Hambly & Fombonne, 2012; Reetzke, Zou, Sheng, & Katsos, 2015). However, most studies have focused on early child development using parent report measures, while less is known about the impact of bilingualism on the linguistic abilities of school-age children with ASD. Furthermore, no previous study has investigated the consequences of bilingualism on the cognitive skills of children with ASD.

In the present dissertation, three studies were conducted to examine the effects of bilingualism on the language and cognition of children with ASD. In the first study, we investigated the lexical and morphological abilities of school-age bilingual children with ASD using standardized tests and we also explored the relationship between amount of language exposure and linguistic competence. The second study examined the impact of bilingualism on verbal fluency, a task that encompasses lexical-semantic as well as executive functioning skills. Finally, in the third study, we investigated the impact of bilingualism on set-shifting and working memory abilities using direct-testing as well as parent report of everyday executive functioning abilities.

Results from these studies indicated that bilingualism confers selective advantages in cognition but not language in school-age children with ASD. First, although performing within the average range, bilingual children with ASD exhibited lower scores relative to their monolingual peers with ASD on standardized measures of vocabulary. No significant differences were found on morphological skills between these two groups (Study 1). Concerning the cognitive domain, bilingual children with ASD showed enhanced performance on the number of correct words produced on a verbal fluency task (Study 2) as well as on an experimental paradigm assessing set-shifting skills. However, advantages were not found on daily life behaviours involving set-shifting abilities as measured by parent report (Study 3). Taken together, these findings build on previous research suggesting that bilingualism is not detrimental for the language skills of children with ASD and provide novel evidence concerning benefits that bilingualism may hold for some executive functioning skills in children on the autism spectrum.

RÉSUMÉ

Certains professionnels conseillent aux parents d'enfants bilingues ayant un Trouble du Spectre de l'Autisme (TSA) de parler à leur enfant en employant une seule langue afin de simplifier l'information que reçoivent ces enfants (Kay-Raining Bird, Lamond, & Holden, 2012; Kremer-Sadlik, 2005). Cette recommandation se base sur la croyance selon laquelle le bilinguisme représente un défi et peut nuire à l'acquisition du langage chez les enfants ayant ce trouble neurodéveloppemental (Kremer-Sadlik, 2005; Yu, 2013). Les quelques études recensées portant sur le développement du langage chez les enfants ayant un TSA ne soutiennent pas cette affirmation. Les résultats indiquent plutôt que les enfants bilingues ayant un TSA ne présentent pas des retards de langage additionnels, comparativement à leurs pairs unilingues ayant un TSA (Hambly & Fombonne, 2012; Reetzke, Zou, Sheng, & Katsos, 2015). Cependant, la majorité des études ont mis l'accent sur le développement de la petite enfance et n'emploient que des mesures et des questionnaires remplis par les parents. La question des impacts du bilinguisme sur les habiletés langagières des enfants d'âge scolaire ayant un TSA demeure moins bien documentée. De plus, aucune recherche n'a exploré les conséquences du bilinguisme sur les habiletés cognitives des enfants ayant un TSA.

Dans la présente thèse, trois études ont été réalisées afin d'examiner les effets du bilinguisme sur le langage et la cognition chez les enfants ayant un TSA. La première étude visait à étudier les habiletés lexicales et morphologiques chez les enfants d'âge scolaire ayant un TSA à l'aide de tests standardisés ainsi que la relation entre la quantité d'exposition au langage et la compétence linguistique. La seconde étude avait pour but d'examiner les effets du bilinguisme sur la fluidité verbale, une tâche englobant les habiletés lexico-sémantiques, ainsi que celles liées aux fonctions exécutives. Finalement, la troisième partie de cette thèse porte sur les impacts du

bilinguisme sur la flexibilité cognitive et les habiletés de mémoire du travail en employant des évaluations directes du langage et des rapports remplis par les parents au sujet des habiletés quotidiennes liées aux fonctions exécutives.

Les résultats de ces trois études révèlent que, chez les enfants d'âge scolaire ayant un TSA et étant exposés à deux systèmes linguistiques, le bilinguisme présente des avantages sélectifs pour la cognition. Cependant, tel n'est pas le cas pour le langage. Tout d'abord, malgré une performance se situant dans la moyenne, comparativement à leurs pairs unilingues ayant un TSA, les enfants bilingues ayant un TSA ont obtenu des scores plus faibles sur des mesures standardisées de vocabulaire. En ce qui concerne les habiletés morphologiques, aucune différence significative n'a été observée entre les enfants bilingues ayant un TSA et leurs pairs unilingues ayant un TSA (Étude 1). Quant aux habiletés cognitives, le nombre de mots corrects produits lors d'une tâche de fluidité verbale était plus élevé chez les enfants bilingues ayant un TSA (Étude 2). De plus, une performance supérieure a été notée lors d'un paradigme expérimental visant à évaluer la capacité de flexibilité cognitive. Cependant, en ce qui a trait aux comportements quotidiens impliquant des habiletés de flexibilité cognitive, telles que mesurées par les questionnaires remplis par les parents, cette étude ne révèle aucun avantage (Étude 3). L'ensemble de ces résultats viennent appuyer les études antérieures avançant que le bilinguisme ne nuit pas aux habiletés langagières des enfants ayant un TSA. Ils offrent également des arguments au sujet des bénéfices que peut avoir le bilinguisme au niveau des fonctions exécutives chez les enfants se trouvant sur le spectre de l'autisme.

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Preface and Contribution of Authors

Autism Spectrum Disorders (ASD) are a prevalent condition characterized by deficits in social communication and interaction, and the presence of repetitive behaviours. To date, research concerning the impact of bilingualism on children with ASD has focused on young children who are exposed to two languages, using parental report to examine their language abilities. The present dissertation makes an original contribution to the field of ASD in three ways: First, by establishing bilingual status through a rigorous combination of measures: Amount of exposure to a second language, direct testing in bilinguals' two languages, and proficiency scores from parents and blind judges; second, this study investigated whether proficient bilingualism is possible for school-age children on the autism spectrum using direct testing, as well as examining the role of amount of language exposure on vocabulary and morphology outcomes; third, this study is novel in examining whether the bilingual advantage hypothesis, which posits that the use of two languages on an ongoing basis yields enhanced executive functioning skills (Bialystok, Craik, Green, & Gollan, 2009), can be extended to children with ASD. This is especially relevant because children with ASD exhibit characteristic deficits in set-shifting abilities, hence it is important to investigate whether bilingualism could act as a protective factor, improving set-shifting ability.

The present dissertation follows a manuscript-based format. First, a general introduction concerning the language and cognitive abilities of children with autism spectrum disorders (ASD) is provided. Then, three manuscripts with their corresponding connections are presented. The first manuscript examines the language skills of proficient bilingual children with ASD relative to monolingual children with ASD. In addition, the influence of amount of language exposure on language performance for typically-developing children, as well as children with

ASD is explored. The second manuscript investigates the performance of bilingual children with ASD relative to three control groups using a measure that involves a combination of executive functioning as well as linguistic knowledge: verbal fluency. In the third manuscript, the executive functioning skills, specifically set-shifting ability, of bilingual and monolingual children with ASD along with their monolingual and bilingual typically-developing peers, are examined using a non-linguistic experimental paradigm and a questionnaire that provides information concerning children's use of executive functioning in daily life. Finally, a general discussion summarising the main findings of the dissertation and highlighting its implications, along with limitations and venues for future research is provided.

I (Ana Maria Gonzalez Barrero) conceptualized and designed all the studies included in this dissertation under the supervision of Dr. Aparna Nadig. I was responsible for experimental design, participant recruitment, data collection, scoring, and data entry with assistance of undergraduate and graduate student research assistants. The design of one of the experimental tasks (nonword repetition) was developed with the collaboration and supervision of Dr. Heather Goad. I was also responsible for data analyses and manuscript writing of all studies under the supervision of Dr. Aparna Nadig. Editorial suggestions and comments were received from Dr. Aparna Nadig, Ph.D. advisor, and dissertation committee members Dr. Fred Genesee and Dr. Elin Thordardottir. Preliminary findings from this dissertation were presented at the following conferences:

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- International Symposium on Bilingualism – ISB 10, New Brunswick, USA, 2015.

- Workshop on Bilingualism and Executive Function – CUNY. New York, USA, 2015.
- International Meeting for Autism Research – IMFAR. Salt Lake City, Utah, USA, 2015.
- Biennial Meeting - Society for Research in Child Development. Philadelphia, USA, 2015.

1. General Introduction

Bilingualism is a phenomenon that has been instrumental in our understanding of the relationship between cognition and language. Widespread interest in this topic likely stems from the belief that the use of multiple languages is an exceptional characteristic for a number of individuals, while monolingualism is the norm (Grosjean, 1982). However, bilingualism is, and has been, a common practice in several societies for centuries (Bialystok, 2001). Furthermore, the current global economy, use of international communications, and increasing number of immigrants have made bilingualism prevalent worldwide (De Groot, 2011).

Since the seminal study by Peal and Lambert (1962) that reported positive effects of bilingualism on cognition, multiple studies have been conducted to examine the consequences of bilingualism on children's linguistic and cognitive skills (e.g., Bialystok & Martin, 2004; Hakuta, 1987; Hoff et al., 2012; Gathercole & Thomas, 2009; Genesee, 1989; Paradis & Genesee, 1996). In the language domain, it has been reported that simultaneous bilingual infants follow a similar pattern of language development to that observed in monolingual infants (Werker & Byers-Heinlein, 2008). Nevertheless, researchers have widely reported lags in some language skills for bilingual children relative to their monolingual peers. For instance, lower vocabulary scores have been found when only one of the languages of the bilingual children is measured (e.g., Bialystok, Luk, Peets, & Yang, 2010; Elin Thordardottir, Rothenberg, Rivard, & Naves, 2006; Ucelli & Paez, 2007). However, when total conceptual vocabulary is examined (i.e., number of concepts regardless of the language in which they are lexicalized and translation equivalents counted only once; Pearson, Fernandez, & Oller, 1993), bilingual children tend to exhibit similar scores relative to their monolingual counterparts (e.g., Pearson et al., 1993; Junker & Stockman, 2002; however, see Elin Thordardottir et al., 2006). Beyond vocabulary, difficulties in lexical access (e.g., Klassert, Gagarina, & Kauschke, 2014; Yan & Nicoladis, 2009; however see Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013), past tense morphology (e.g., Paradis, Nicoladis, Crago, & Genesee, 2011), and grammatical complexity (e.g., Hoff et al., 2012) have also been described for bilingual children when compared to their monolingual peers. Of interest, it has been argued that differences in the rate of lexical and grammatical acquisition observed in bilinguals relative to monolinguals are closely related to the amount of language exposure bilingual children receive in each of their languages (e.g., Hoff et al., 2012; Elin Thordardottir, 2011); as a result, amount of language exposure has a central role in studies of language development in bilingual populations.

In the cognitive domain, researchers have generally found advantages for bilingual children relative to monolinguals (e.g., Martin-Rhee & Bialystok, 2008; Carlson & Meltzoff, 2008; however see Morton & Harper, 2007). For example, bilingual children have been reported to outperform their monolingual peers on various executive functioning tasks such as the Dimensional Change Card Sort Task (DCCS), the Simon task, and the Stroop task (e.g., Barac & Bialystok, 2012; Bialystok & Martin, 2004, Martin-Rhee & Bialystok, 2008; Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011). Nevertheless, the bilingual advantage has not been found consistently in other studies (e.g., Engel de Abreu, 2011, Morton & Harper, 2007; Namazi & Elin Thordardottir, 2010). To illustrate, Morton and Harper (2007) did not find enhanced cognitive control for bilingual children relative to their monolingual peers using the Simon task. Specifically, the bilingual group did not exhibit faster reaction times (RT) or more accurate performance in comparison to the monolingual group. Similar results (i.e., absence of a bilingual advantage) were found by Paap and Greenberg (2013) in bilingual university students using tasks that tap cognitive flexibility and cognitive control (i.e., color-shape switching task, flanker task, and Simon task). In contrast, Bialystok and Viswanathan (2009) reported advantages for bilingual children when compared to same-age monolingual peers in tasks that assess cognitive flexibility (i.e., faces task and trail-making task). Taken together, the previously cited studies show that evidence concerning the effects of bilingualism on cognitive skills is mixed and research that systematically controls for relevant variables that may influence these results (e.g., socio economic status, language proficiency, etc.) is warranted.

Contrary to studies on typically-developing bilingual children, research concerning the effects of bilingualism on the language and cognitive development of bilingual children with neurodevelopmental disorders is scarce (Kohnert & Medina, 2009; Uljarević, Katsos, Hudry, & Gibson, 2016). Special attention has been given to children with specific language impairment (e.g., Elin Thordardottir & Brandeker, 2013; Paradis, Crago, Genesee, Rice, 2003; Sheng, Peña, Bedore, & Fiestas, 2012) and those with Down syndrome (e.g., Kay-Raining Bird et al., 2005; Cleave, Kay-Raining Bird, Trudeau, & Sutton, 2014; Feltmate & Kay-Raining Bird, 2008). However, there have been few studies to date investigating the language development of bilingual children with autism spectrum disorders (Drysdale, van der Meer, Kagohara, 2015; Kay-Raining Bird, Genesee, & Verhoeven, 2016) and, to our knowledge, none on the cognitive effects of bilingualism in this group.

Considering that the majority of the available literature has focused on typically-developing children who are learning two languages, the purpose of this dissertation was to explore the effects of bilingualism on language and cognition on children with an increasing prevalent condition, namely, autism spectrum disorders (ASD). This condition is of particular interest because it is often presumed that children with ASD cannot become proficient bilinguals, due to characteristic social impairments as well as language delays observed in many of them

(Kremer-Sadlik, 2005). Specifically, this dissertation examined whether proficient bilingualism is possible for children with ASD by investigating the linguistic abilities of this group relative to their monolingual peers with ASD, as well as the relationship between amount of language exposure and language proficiency in vocabulary and morphological skills in this population. After answering this question, our second aim was to extend the bilingual advantage hypothesis in executive functions (EF) to ASD, using both a verbal (i.e., verbal fluency) and a non-verbal paradigm (i.e., Dimensional Change Card Sort task; Zelazo, 2006). This is especially relevant because of characteristic EF impairments, particularly in set-shifting skills (Eigsti, 2011), which will be discussed in more detail in section 1.1.3.

The implications of the present dissertation are both practical and theoretical. On the practical side, this dissertation aims to provide empirical evidence that can inform clinicians' advice and parents' decisions concerning the consequences that bilingualism has on language and executive functioning for children with ASD. These findings may impact the way children with ASD are raised and the languages they are exposed to early in life. On the theoretical side, this study aims to extend the bilingual advantage hypothesis to children with a neurodevelopmental disorder. Specifically, we explore if set-shifting impairments are reduced in proficient bilingual children with ASD. Taken together, results from this dissertation add to the sparse body of knowledge on language and cognitive development in bilingual children with ASD. Particularly, they increase our understanding of the capacity for dual language learning in children with ASD and how mechanisms that are thought to underlie cognitive effects in typically-developing bilingual children are implicated in children with ASD.

A review of the most relevant literature concerning language skills and executive functioning in bilingual children with ASD is provided in each of the three manuscripts that comprise the current dissertation. In the following section, a general introduction describing the main features that characterize the language and cognitive skills of children with ASD is provided.

1.1 Autism Spectrum Disorders.

Autism Spectrum Disorders (ASD) are neurodevelopmental disorders characterized by deficits in social communication and interaction accompanied by restricted interests and repetitive behaviors (American Psychiatric Association, 2013). ASD are considered a common condition, with a prevalence estimate of 1 in 88 children (Anagnostou et al., 2014; Baio, 2012). The etiology of ASD remains unknown; however, it is currently hypothesized that a combination of genetic and environmental factors plays a role in the development of this condition (Herbert, 2010; Persico & Bourgeron, 2006). Epidemiological data have shown that ASD is more prevalent among males than females (Christensen, 2016), although the specific factors that underlie this difference have not yet been determined (Anagnostou et al., 2014). Since the introduction of the concept of *autism* by Kanner in 1943, the definition of ASD has undergone major changes over the years (Verhoeff, 2013). However, *language* and *cognition* have consistently been major topics of interest in the field, given the difficulties exhibited by individuals with ASD in these domains (Baron-Cohen, 1988).

1.1.2 Language Abilities in Autism Spectrum Disorders.

Children with ASD exhibit great variability in their language abilities, ranging from minimally verbal (approximately 25% to 35% of children with ASD; Rose, Trembath, Keen, & Paynter, 2016) to relatively intact or even above average structural language skills (Kelley, 2011). Language is often defined as a primary area of difficulty for this population (Tager-Flusberg, Paul, & Lord, 2005) and it has been found that children with ASD, as a group, show early language delays relative to their typically-developing peers (Charman, Drew, Baird, &

Baird, 2003). In fact, language delays at early ages are one of the first concerns reported by parents of children with ASD (Mitchell et al., 2006; Tager-Flusberg, 2000). Early in development, infants with ASD show reduced use of deictic (e.g., pointing) and conventional (e.g., nodding head) gestures as well as difficulties with the comprehension of common social phrases (e.g., *"give it to Mommy"*; Mitchell et al., 2006). Furthermore, deficits in joint attention (Loveland & Landry, 1986), decreased response to their own name (Nadig et al., 2007), and late onset of first words (Tager-Flusberg et al., 2005) have also been identified in very young children on the autism spectrum.

Several studies have been conducted examining the language skills of children with ASD (e.g., Geurts & Embrechts, 2008; Haebig, Kaushanskaya, & Weismer, 2015; Kjelgaard & Tager-Flusberg, 2001; Nadig, Vivanti, & Ozonoff, 2009). Special attention has been paid to pragmatic abilities, which are one of the core features involved in the diagnosis of ASD (American Psychiatric Association, 2013). Specifically, pragmatics has been described as a linguistic domain in which individuals with ASD exhibit persistent difficulties regardless of age (Kelley, 2011; Tager-Flusberg et al., 2005). Deficits in the social use of language, such as poor topic maintenance (Nadig, Lee, Singh, Bosshart, Ozonoff, 2010), atypical eye contact, difficulty with the interpretation of non-literal language, and deficits understanding nonverbal gestures, are some of the main impairments reported in individuals with ASD (Philofsky, Fidler, & Hepburn, 2007).

Other language abilities that have been of major interest in the field of ASD are lexical-semantic skills. Overall, researchers have reported that vocabulary seems to be an area of strength for children on the autism spectrum, relative to other linguistic domains (Tager-Flusberg, 2000). However, heterogeneous vocabulary profiles are not uncommon for children with ASD (Anderson et al., 2007), with some children acquiring a limited number of words, while others exhibit extensive vocabularies, in some cases related to their particular interests (Frith & Happé, 1994b). Concerning semantic skills, various studies have reported that children with ASD are able to map words to novel objects (Bani Hani, Gonzalez-Barrero, & Nadig, 2013; Luyster & Lord, 2009; Norbury, Griffiths, & Nation, 2010) and to categorize objects into different perceptual dimensions (Ungerer & Sigman, 1987).

Researchers have also documented specific features of the lexical profile of individuals with ASD, such as the use of idiosyncratic words (e.g., It makes me want to go *as deep as economical with it*; Volden & Lord, 1991, p. 116), neologisms (e.g., "*bloosers"* for bruisers, Volden & Lord, 1991), and pedantic speech (i.e., provision of more information that what is needed for the context; Ghaziuddin & Gerstein, 1996). Another commonly reported characteristic of the language of children with ASD, specifically those with low expressive abilities is *echolalia*, defined as the immediate or delay repetition of the same words used by others (Tager-Flusberg, 2000). Finally, pronoun reversal (e.g., *you* instead of *I*; Frith & Happé, 1994b) has also been observed in some children on the spectrum.

Concerning the morphological abilities of monolingual children with ASD, studies have showed contradictory results, with some researches reporting morphological skills in line with children's mental age, while others have found deficits on some morphological structures (Eigsti, de Marchena, Schuh, & Kelley, 2011). One study that found such deficits was conducted by Eigsti, Bennetto, and Dadlani (2007). In this study, 16 children with ASD (age range 3 to 6), were matched on nonverbal IQ, age, and gender to a group of children with developmental delays. A younger typically-developing (TYP) group was also included and was matched to the other groups on nonverbal IQ and gender. Analyses of 100 utterances from a free-play interaction showed that children with ASD exhibited shorter mean length of utterance (MLU) relative to the group with developmental delays, although this result did not reach significance when compared to the TYP group. In addition, children with ASD produced less complex language relative to both control groups as measured by the index of productive syntax (IPSyn). Of interest, Eigsti and colleagues argued that the syntactic development of children with ASD does not follow the typical pattern found in other populations, given inconsistencies found in syntactic measures.

Grammaticality judgement tasks have also been used to assess the morphological skills of children with ASD. One of these studies was carried out by Eigsti and Benneto (2009). In their study, the authors explored the performance of monolingual English-speaking children with ASD in a grammaticality judgement task. Participants were high-functioning children and adolescents with ASD (age range 10-17) who were matched with a TYP group on several variables (age, vocabulary, gender, SES, and IQ). Results showed that there were no significant differences between groups in the judgment of several grammatical structures (e.g., aspect marking, plurals, auxiliaries, determiners, word order, and pronominalization). However, children with ASD exhibited difficulties relative to their TYP peers in identifying grammatical violations only for sentences that include the third-person singular or the present progressive. Based on these findings, the authors suggested that "it is general learnability process, rather than particular grammatical structures, that are driving group differences" (Eigsti & Benetto, 2009, p. 1017). In a separate study by Terzi and colleagues (2012), it was reported that the only structure for which high functioning Greek-speaking children with ASD (age range 5 to 8) exhibited difficulties relative to their TYP counterparts was clitic pronouns. No other significant differences were found between the groups, even for linguistic forms described as difficult in Greek, such as passives (Terzi, Marinis, Francis, & Kotsopoulou, 2012).

Notably, a subgroup of children with ASD exhibit concomitant language impairment (Kjelgaard & Tager-Flusberg, 2001). For example, Tager-Flusberg and Joseph (2003) conducted a study with 44 children with ASD (age range 5 to 15 years). Participants included 10 children without language impairment (i.e., language scores within 1SD above or below the mean on the total score of the Clinical Evaluation of Language Fundamentals – CELF, Wiig et al. 1992; Semel et al. 1995), 13 children whose language skills were categorized as borderline (i.e., CELF language scores below 1SD), and 21 children with language impairment (i.e., CELF total scores 2SD below the mean). Findings from Tager-Flusberg and Joseph's (2003) study revealed that, while the group with ASD without LI scored within the average range on several standardized tests (i.e., receptive and expressive vocabulary, articulation, grammatical abilities, and nonword repetition), children with ASD in the borderline subgroup as well as those classified as having language impairment (LI) exhibited deficits in vocabulary, syntax, semantics, and nonword repetition. However, their articulation skills were intact. These results led the authors to argue that the profile of the children with ASD+LI was remarkably similar to that observed in children with Specific Language Impairment (SLI). However, there is a controversy concerning whether children with ASD and SLI share the same phenotype (Kjelgaard & Tager-Flusberg, 2001; Tager-Flusberg and Joseph, 2003) or if similarities between these conditions are only superficial and are better explained by different underlying causes (Taylor, Maybery, & Whitehouse, 2012; Whitehouse, Barry, & Bishop, 2007).

Although some researchers have investigated the areas of articulation and phonology in children with ASD (e.g., Cleland, Gibbon, Peppé, O'hare, & Rutherford, 2010; Shriberg, Paul, Black, & van Santen, 2011), less evidence is available for these linguistic domains. Regarding articulatory and phonological skills, a study by Boucher (1976) in which a standardized test was used (i.e., the Edinburgh Articulation Test; Anthony, Bogle, Ingram, & McIsaac, 1971) showed that children with ASD had better scores relative to children with language impairment, which led Boucher (1976) to conclude that articulation was a domain in which children with ASD exhibit spared skills. Similar findings were reported in a seminal study by Kjelgaard and Tager-Flusberg (2001) using the Goldman-Fristoe Test of Articulation (GFTA; Goldman & Fristoe, 1986). These authors argued that despite difficulties in other language domains such as semantics and morphology, articulation seemed to be a relative strength in the language profile of school-age children with ASD.

These results have been challenged by some researchers who have found speech difficulties in these children (e.g., Cleland, Gibbon, Peppé, O'hare, & Rutherford, 2010). For example, in a study with 70 children with ASD in which the GFTA-2 was used, Cleland and colleagues (2010) found that 41% of school-age children with ASD (mean age 9,6) still exhibited a small number of speech errors, the most common being gliding, cluster reduction, and deletion of final consonants. These findings led the authors to conclude that speech production seems to be delayed in some children with ASD (Cleland et al., 2010).

In summary, despite some contradictory findings, the available evidence suggests that phonological and articulatory skills are considered relative areas of strength for children with ASD, relative to other areas of language.

The studies presented thus far confirm the heterogeneity in the language skills of children with ASD and highlight the importance of taking into consideration the structural language abilities of children with ASD (e.g., the presence or absence of language impairment) when examining their language skills. Overall, pragmatics is a domain in which children with ASD exhibit characteristic deficits, while a subgroup of children with ASD show difficulties with structural language and phonology. Articulation seems to be an aspect of language that is relatively spared in this population.

Next, we turn to a brief review of the main characteristics and theoretical accounts that have been postulated to explain the cognitive phenotype of individuals on the autism spectrum.

1.1.3 Cognition in Autism Spectrum Disorders.

A considerable number of studies has been published concerning the cognitive phenotype of individuals with ASD (e.g., Joseph, Tager-Flusberg, & Lord, 2002; Mottron & Burack, 2001; Ozonoff & McEvoy, 1994; Pellicano, 2010; Russo et al., 2007;). Mirroring findings from the language domain, it has been reported that children with ASD exhibit heterogeneous cognitive profiles, with some presenting low intellectual abilities (IQ <70, approximately 31% of the population; Baio, 2014), while others present average or exceptionally high IQ scores (Charman et al., 2011). Other areas of investigation with respect to cognitive profiles in ASD include individual differences in uneven verbal and nonverbal IQ (e.g., Joseph et al., 2002) and enhanced perceptual abilities (e.g., Mottron, Peretz, & Menard, 2000; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Shah & Frith, 1983), among others.

1.1.3.1 Cognitive Theories of Autism Spectrum Disorders.

Different theoretical accounts have been postulated regarding the cognitive phenotype of individuals with ASD (Charman et al., 2011). However, three theories are considered the more influential cognitive accounts of ASD (Pellicano, 2010; Rajendran & Mitchell, 2007), namely, the *theory of mind hypothesis*, the *"weak" central coherence theory*, and the *executive dysfunction hypothesis*.

The *theory of mind deficit hypothesis* (Baron-Cohen, Leslie, & Frith, 1985) states that children with ASD exhibit deficits with the representation of mental states and with the attribution of these to others (Baron-Cohen et al., 1985). Accordingly, individuals with ASD show impairments understanding that people might have different beliefs from those they have, which in turn affects their ability to predict the behaviours of others (Baron-Cohen, 1989). Although this theory has offered theoretical support to explain the deficits in social-cognition exhibited by individuals on the spectrum (e.g., deficits in non-verbal communication), it has been argued that it does not account for other specific characteristics observed in ASD, such as impairments on non-social aspects (e.g., restricted interests, insistence on sameness, etc; Frith & Happé, 1994a). In addition, some researchers have criticized the lack of universality of this theory (Ozonoff, Pennington, & Rogers, 1991) insofar as not all individuals with ASD fail paradigms used to assess theory of mind (i.e., false-belief tasks). These shortcomings led other authors to propose further accounts that could better explain the cognitive profile of individuals with ASD.

Another account that has aimed to explain some of the cognitive characteristics observed in ASD is the *weak-central coherence hypothesis* (Frith, 1989; Happé & Frith, 2006). According to this theory, deficits in the integration of global information are the underlying cause of the characteristic cognitive profiles of individuals with ASD (Frith, 1989). Specifically, a lack of central coherence, meaning a tendency to focus on local information rather than appraising the global meaning of a feature or situation, is what governs the cognitive mechanisms underlying ASD (Frith, 1989; Happé & Frith, 2006). This cognitive account focuses primarily on the non-social aspects observed in the autism phenotype (Charman et al., 2011), such as enhanced perceptual abilities (e.g., superior discrimination of pitch changes; Bonnel et al., 2003). A plethora of studies has been conducted in which the central coherence account has been investigated (e.g., Happé, Briskman, & Frith, 2001; López, Donnelly, Hadwin, & Leekam, 2004; Morgan, Maybery, & Durkin, 2003). Nonetheless, mixed findings have been reported when assessing this theory, such as intact global processing in some individuals with ASD (Mottron, Burack, Stauder, & Robaey, 1999; Mottron et al., 2000). These results have led yet other theorists to propose alternative theoretical accounts that try to better explain the cognitive characteristics observed in this condition (e.g., Mottron, Dawson, Soulieres, Hubert, & Burack, 2006; Plaisted, 2001).

One of these alternative accounts is the *theory of executive dysfunction* (Ozonoff et al., 1991). This theory posits that executive function deficits are the primary underlying cause of the cognitive deficits present in ASD. *Executive functions* have been defined as cognitive abilities that are hypothesized to rely on the frontal lobes, including cognitive flexibility, inhibition, planning, cognitive control, and organization (Ozonoff, 1995a). The proponents of the *executive dysfunction hypothesis* conducted experimental paradigms assessing both theory of mind and executive function (EF) in individuals with ASD. While some participants with ASD passed the theory of mind experimental tasks, the vast majority exhibited impairments in two tasks of EF, the Wisconsin Card Sorting task, which examines mental flexibility, and the Tower of Hanoi task, which assesses planning skills (Ozonoff et al., 1991).

It has been postulated that executive dysfunction underlies several of the characteristics observed in ASD, such as perseveration, repetitive behaviours, and difficulties changing and initiating new tasks (Hill, 2004). Nonetheless, as with other cognitive theories, some researchers have acknowledged some weaknesses in the *executive dysfunction account*. For example, Hill (2004) described limitations such as uncertainty concerning the specific EF skills affected in

ASD, the lack of specificity of executive dysfunction as a primary characteristic of ASD, given that it also affects other developmental disorders (e.g., Attention Deficit Hyperactivity disorder, ADHD), and the heterogeneous EF profiles individuals with ASD present. Accordingly, further research is needed concerning the primary EF skills that are impaired in children with ASD.

Despite these shortcomings of the *executive dysfunction account* as the “unitary” theory that can account for the cognitive profile of all individuals with ASD, there is empirical evidence supporting executive functioning deficits in this population (for a comprehensive review see Hill, 2004) in experimental tasks as well as in everyday skills. To illustrate, researchers have reported impairments on executive functioning skills such as planning and set-shifting in children with ASD relative to children with moderate learning disabilities and typically-developing children using experimental tasks (Hughes, Rusell, & Robbins, 1994). Similarly, a study by Gioia, Isquith, Kenworthy, and Barton (2002) found executive functioning impairments in children with ASD relative to typically-developing children using a parent questionnaire that assessed behaviours in daily life (i.e., Behavior Rating Inventory of Executive Function-BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000). Of particular interest, although Gioia and colleagues (2002) reported difficulties in several executive functioning domains in children with ASD (e.g., inhibition, planning, monitoring, etc.), shifting was the ability in which children with ASD exhibited the greatest deficits relative to typically-developing controls, as well as to children with other acquired and developmental disorders.

In sum, to date, no single theory has had the explanatory power needed to account for all the cognitive characteristics exhibited by individuals with ASD (Rajendran & Mitchell, 2007). Consequently, researchers in the field of ASD have proposed to consider a multifactorial account that takes into consideration a developmental approach to explain the particular characteristics of this condition (Pellicano, 2010; Rajendran & Mitchell, 2007). Nonetheless, executive dysfunctions have been found in individuals with ASD regardless of their developmental level (Hill, 2004). Accordingly, more studies examining the executive functioning abilities of children on the autism spectrum are needed to provide further evidence concerning the areas of difficulty as well as strengths exhibited by these children. In particular, the identification of cognitive strengths in individuals with ASD can help clinicians use these skills to improve other cognitive abilities that are challenging for this population (Charman et al., 2011).

The section that follows addresses the relationship between ASD and bilingualism, discussing the potential advantages of bilingualism on executive functioning for individuals with ASD.

1.1.4 The bilingual advantage hypothesis in Autism Spectrum Disorders.

The *bilingual advantage hypothesis* posits that living as a bilingual and using two linguistic systems involves increased demands on multiple cognitive mechanisms. In turn, this ongoing practice is thought to yield more global advantages in the same executive functioning skills that are tapped by using two languages (Bialystok et al., 2009; Prior & MacWhinney, 2010). More specifically, (active and proficient) bilinguals continuously *switch* between two languages to successfully meet the demands of their communication context. Similarly, they need to *monitor* the language being used, while *inhibiting* the language that is not required for the communicative interaction (Bialystok, 2007). Since all of these cognitive functions entail engagement of what is known as *executive functioning*, it is suggested that bilingualism leads to positive consequences in the broader cognitive domain, given the constant use of executive function abilities by bilingual speakers (Bialystok, 2007; Bialystok, 2009).

The question arises: Is it possible for a bilingual advantage to be observed in children with ASD? To answer this question, it is fundamental to break down the process that is hypothesized to lead to an advantage in executive function for bilinguals. First, it is necessary that bilinguals in question are *proficient* in their two languages, given that it is the continuous use of two linguistic systems that is thought to yield enhanced switching abilities (i.e., set-shifting). Previous research on the initial stages of language development in bilingual children with ASD suggests that bilingualism is possible in this population (Hambly & Fombonne, 2012; Ohashi et al., 2012; Petersen et al., 2012; Valicenti-McDermott et al., 2013). Yet, although bilingual children with ASD have been reported to achieve early language milestones at similar ages as monolingual children with ASD (Hambly & Fombonne, 2012), whether these children can become *proficient bilinguals* has not yet been examined. A related question is how bilingualism impacts linguistic abilities at school age, when more complex vocabulary and grammar should be mastered. Accordingly, in Study 1, we investigate the language skills of school-age bilingual children with ASD relative to monolingual children with ASD to confirm whether children on the autism spectrum can become *proficient bilinguals* and the profile they exhibit in standardized language tests.

While Study 1 is driven primarily by applied and clinical motivations, Study 2 examines a more theoretical perspective. Returning to the mechanisms thought to underlie the bilingual advantage, set-shifting (also known as cognitive flexibility) is hypothesized to be enhanced by bilingualism (e.g., Bialystok & Viswanathan, 2009), given the need to successfully *switch* between languages to fulfil the demands of a communicative interaction. Interestingly, set-shifting has been consistently reported to be impaired in individuals with ASD (e.g., Ozonoff, 1995a; Shu, Lung, Tien, & Chen, 2001). In fact, set-shifting impairments are closely related to some of the core deficits of ASD (i.e., presence of repetitive patterns of behaviour such as rigid thinking, difficulties with transitions, and inflexible routines; APA, 2013). Consequently, we can hypothesize that, if bilingualism provides advantages in set-shifting skills, it is possible that children with ASD who are proficient bilinguals, may show enhanced performance on set-shifting tasks relative to monolingual children with ASD who do not regularly need to switch between languages. To examine this possibility, we used a verbal fluency task that requires the use of both language skills and executive functioning skills (Friesen, Luo, Luk, & Bialystok, 2015), such as set-shifting (e.g., switching between categories or items), generativity (e.g., ability to name new elements to correctly perform the task), and monitoring (e.g., being aware of elements previously named to avoid repetition).

Finally, in Study 3, we further explore the bilingual advantage hypothesis, this time extending the investigation of whether the use of two languages leads to advantages in set-shifting to a non-verbal task. It might be possible that advantages cannot be observed in a paradigm that involves language production, as is the case of verbal fluency, since bilinguals have been reported to exhibit poor lexical retrieval (Bialystok et al., 2009). Accordingly, we used the Dimensional Change Card Sort task (DCCS; Zelazo, 2006) to examine if a bilingual advantage is observed in the nonverbal modality. Finally, we explore whether bilingualism confers advantages in set-shifting that can be observed in the activities of daily life (e.g., whether a child has difficulty with transitions between activities at school). This allows us to disentangle whether performance observed in experimental paradigms can translate to the more complex real-life situations.

2. General Methods

2.1 Participants

For the present dissertation, 114 participants (65 typically-developing children and 49 children with ASD) were recruited and tested over two years (February 2014 – April 2016). Bilingual participants were tested in both of their languages during two separate sessions, while monolinguals were typically tested in one session. However, given the age (5 to 10 year-olds) and the behavioral difficulties exhibited by some participants with ASD, more than two sessions were required in some cases; this was also true even for some monolingual children. In addition, some children with ASD as well as some typically-developing (TYP) children were reluctant to participate in some tasks for different reasons, and we respected their requests. Therefore, the sample size of the different studies included in this dissertation varies depending on the data available for the specific tasks.

The studies that comprise this dissertation focus on school-age simultaneous bilingual children or very early sequential bilingual children (age of acquisition of L2 before age 4). Our operational definition of bilingualism is provided in detail in each manuscript, and participant inclusion as well as matching is described in each study.

2.2 Procedure

The present project was conducted in Montreal, Quebec, Canada. The general procedure of the study is described in each manuscript. An outline of the study protocol is provided below, including standardized measures and experimental tasks. Not all tasks administered are included in the three manuscripts of this dissertation due to space constraints.

General Procedure

Test/Task	Measure
Leiter-R*	Non-verbal IQ
CELF-4 (word structure)	Morphology
CELF-4 (Recalling sentences)	Sentence Repetition
CELF-4 (Number repetition)	Short-term and working memory
Computerized Dimensional Change Card Sort task (DCCS)*	Set-shifting
PPVT	Receptive vocabulary
Nonword repetition	Phonological short-term memory
Verbal fluency	Executive functioning and Lexical-semantic skills
Language sample	Spontaneous language

**Administered only once to bilingual participants*

3. Manuscript 1

Bilingualism and Autism Spectrum Disorders: The impact of amount of language exposure on vocabulary and morphological skills

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ABSTRACT

Purpose. Most studies with bilingual children with Autism Spectrum Disorders (ASD) have focused on initial stages of language development using parent report measures. However, the effect of bilingualism on linguistic abilities at school age when more complex language is generally acquired is unknown. We examined the vocabulary and morphological skills of school-age monolingual and bilingual children with autism spectrum disorders as well as the role of amount of language exposure on these skills.

Method. Eighteen school-age children with ASD (9 monolingual and 9 bilingual) were assessed using standardized measures of vocabulary and morphology. Participants' languages included English, French, and Spanish. Bilingual status was confirmed by a combination of direct testing and parent report. Multiple regression analyses were conducted to examine the predictive role of current amount of language exposure on language measures in a larger sample of children with different amounts of exposure to French (47 typically-developing children and 30 children with ASD).

Results. Monolingual children with ASD tended to outperform the bilingual group on vocabulary measures, similar to findings reported for typically-developing children. No significant differences were found between groups on morphology scores. The bilingual group with ASD performed within the average range on standardized tests of both vocabulary and morphology in their dominant language. Regression analyses showed that current amount of language exposure was the strongest predictor of these language abilities for both typically-developing children and children with ASD.

Conclusions. These findings provide further evidence that, when provided with optimal opportunities, some children with ASD are capable of acquiring two languages. In addition, they

demonstrate the central role played by amount of language exposure in vocabulary and morphological development in children with ASD.

Keywords: *Bilingualism, Autism Spectrum Disorders, Vocabulary, Morphology, Language Exposure*

Imagine you speak a language at home but live somewhere where another language is used in public life. You have a child with an Autism Spectrum Disorder (ASD), which is often associated with language delays (Luyster, Kadlec, Carter, & Tager-Flusberg, 2008). Should you raise your child bilingually? While several studies have been conducted to understand the impact of bilingual language exposure on typical development (e.g. De Houwer, 2007; Hoff et al., 2012; Paradis & Genesee, 1996; Elin Thordardottir, 2011), less is known about the role that bilingual language exposure plays in the language development of children with neurodevelopmental disorders (Kay-Raining Bird, Genesee, & Verhoven, 2016; Uljarevic, Katsos, Hudry, & Gibson, 2016). In the present study, we examined how bilingual children with ASD perform on standardized tests relative to their monolingual ASD peers. In addition, we investigated the contribution of current amount of language exposure to variation in children's vocabulary and morphological skills, providing new insight into the relationship between amount of language exposure and language performance in bilingual children with ASD.

Bilingualism in Autism Spectrum Disorders

Autism Spectrum Disorders (ASD) are neurodevelopmental disorders characterized by deficits in social communication and interaction accompanied by repetitive behaviors and restricted interests (American Psychiatric Association, 2013). Given the characteristic communication impairments observed in children with ASD, some professionals advise parents of bilingual children with ASD to use only one language when interacting with their children (as reported by Jegatheesan, 2011; Kay-Raining Bird, Lamond, & Holden, 2012). This advice stems from the belief that bilingualism may be harmful for language acquisition in children with ASD (Kay-Raining Bird et al., 2012; Kremer-Sadlik, 2005; Yu, 2013). However, the available evidence does not support this claim (e.g., Drysdale, van der Meer, & Kagohara, 2015; Hambly

& Fombonne, 2012; Ohashi et al., 2012; Reetzke, Zou, Sheng, & Katsos, 2015; however see Chaidez, Hansen, & Hertz-Picciotto, 2012). In fact, the few studies that have examined the language skills of bilingual children with ASD (for a comprehensive review see Kay-Raining Bird et al., 2016) have reported that, when provided adequate opportunities, children with ASD exposed to two languages do not lag behind their monolingual peers with ASD on early language milestones (Hambly & Fombonne, 2014; Petersen, Marinova-Todd, & Mirenda, 2012).

One of the first published studies on this topic was conducted by Hambly and Fombonne (2012). In their study, 75 children with ASD (30 monolinguals and 45 bilinguals) between 3 and 6 years of age were included. Bilingual status was determined based on the child's history of exposure to more than one language. Furthermore, bilingual participants were divided into simultaneous (i.e., exposure to two or more languages before 12 months of age; n = 24) or sequential (n = 21; exposure to a second language after 12 months of age) bilinguals. Participants' language backgrounds included an array of languages (e.g., Hebrew, Italian, Tamil, English, and French, among others). Language skills were assessed using the MacArthur Communicative Developmental Inventories: Words and Sentences (MCDI; Fenson et al., 1993), a commonly used parent report measure that provides information regarding child vocabulary development. Early language milestones (i.e., age of first words and age of first sentences) and scores from the receptive and expressive communication-scales from the Vineland Adaptive Behavior Scales-Second Edition (VABS-II; Sparrow, Cicchetti, & Balla 2005) were also examined. Results showed that total conceptual vocabulary (i.e., number of words for concepts regardless of language in which they are lexicalized; Pearson, Fernandez, & Oller, 1993) and the number of words in the child's dominant language did not differ across the three groups. Similarly, the monolingual, simultaneous bilingual, and sequential bilingual groups had comparable ages of onset of language milestones and similar performance in their receptive and expressive VABS-II scores. Of interest, the two former groups tended to exhibit higher language scores overall than the sequential bilingual group, although statistically significant differences were not found. Based on these findings, the authors concluded that these children with ASD, who were growing up in a bilingual context, did not present with additional language delays when compared with monolingual children with ASD.

Other researchers have found similar evidence for young children with ASD. For instance, Ohashi and colleagues (2012) reported similar scores for bilingual (English and various languages or French and various languages, n = 20) and monolingual (either English or French-speaking, n = 40) toddlers with ASD matched on age and nonverbal IQ (NVIQ), using language measures administered in the dominant language of the bilingual children (i.e., auditory comprehension and expressive communication sub-scales of the Preschool Language Scale 4th edition; PLS-4, Zimmerman et al., 2002). Similarly, in a retrospective study, Valicenti-McDermott and colleagues (2013) reported comparable performance on receptive and several early expressive measures (e.g., babbling and number of words) for 40 bilingual (English-Spanish) and 40 monolingual (English-speaking) toddlers with ASD. Of interest, some differences were found that favored the bilingual group, namely, percentage of cooing and use of gestures (e.g., pointing).

Further evidence that bilingualism does not negatively affect the language development of bilingual children on the autism spectrum was provided by Petersen, Marinova-Todd, and Mirenda (2012). Petersen and colleagues compared the language skills of 14 bilingual children with ASD (Chinese-English) to those of 14 monolingual English-speaking children with ASD (mean age 4;9 years). Language measures included the Peabody Picture Vocabulary Test (PPVT-

III, Dunn & Dunn, 1997) and its Chinese version (Lu & Liu, 1994). Furthermore, two subscales (i.e., auditory comprehension and expressive communication) of the Preschool Language Scales (PLS-3; Zimmerman et al., 1992) were used to assess the children's language skills and the MCDI was completed by the participants' parents. Results revealed that total conceptual vocabulary and scores on the subscales of the PLS-3 did not differ significantly between groups. However, participants were not matched on NVIQ and results showed significant differences on this variable across groups, with bilingual children with ASD outperforming monolingual children with ASD. Since NVIQ has been reported to be a strong predictor of receptive and expressive language skills in children with ASD (Thurm, Lord, Lee, & Newschaffer, 2007), it is important to match children on this variable from study onset (as suggested by Petersen et al., 2012).

More recently, research by Reetzke, Zou, Sheng, and Katsos (2015) found comparable performance in a sample of Chinese bilingually exposed children with ASD and monolingual children with ASD. Reetzke and colleagues' study included 23 bilingually exposed (Mandarin-Chinese minority language) and 21 monolingual (Mandarin or other Chinese language) children with ASD (age range 3;9 to 8;2 years). Determination of bilingual status was based only on parent report without direct testing of the children's second language (L2). Accordingly, the authors made an important distinction between the concepts of *bilingual* (i.e., ability to communicate in two languages) and *bilingually exposed* (i.e., exposure to two languages regardless of level of proficiency) children, focusing on the latter in their study. The bilingually exposed group and the monolingual group did not differ on age, socio-economic status (SES), or autism severity. Language abilities were measured using a Chinese version of the Children's Communication Checklist-2 (CCC-2; Bishop, 2006). This questionnaire consists of 70 items that provide information about the child’s structural language skills as well as pragmatic abilities. Results showed that although both groups scored below the average range on most of the language measures, there were no significant differences between the bilingually exposed and monolingual children on any of the CCC-2 subscales.

While the use of parent questionnaires and direct assessment of language skills have been reported to correlate highly at early ages for children with ASD, particularly for the expressive domain (Luyster et al., 2008), as the child grows up, it becomes more challenging for parents to accurately estimate the child’s language proficiency. This is especially true when the child is bilingual and one language is spoken at home while the other is used in academic settings or with friends. Thus, direct language testing is warranted with older children to have a more comprehensive account of their communication abilities in both languages.

In addition, although the previously discussed research has provided valuable information regarding the language skills of bilingual children with ASD, most studies on bilingualism and ASD have examined early language development (e.g., prior to age 6), while less is known about the language abilities of school-age children. Moreover, parent report or retrospective data have been used to assess children’s language skills, with just two studies assessing directly both languages of the bilingual ASD group (i.e., Petersen et al., 2012; Valicenti-McDermott et al., 2012). More important, as pointed out by Reetzke and colleagues (2015), most studies on bilingualism and ASD have examined the language abilities of *bilingually exposed* children, while the language skills of *bilingual (i.e., proficient bilingual)* children with ASD is an understudied topic.

What is the importance of studying this specific group of children with ASD? During the school-age years, children with ASD, like typically-developing (TYP) children, continue developing their language skills and more complex aspects of vocabulary and grammar are usually acquired in this stage (Tager-Flusberg, Paul, & Lord, 2005). Accordingly, close examination of the language skills of older children with ASD is essential to understand the full effects of bilingualism in a population that exhibits early language delays (Luyster, Lopez, & Lord, 2007). Similarly, the characterization of language abilities in these children provides information to clinicians and educators that work with this population concerning the profile of language abilities that can be expected for bilingual children with ASD on standardized measures of language proficiency relative to a central factor, namely, amount of language exposure. Accordingly, the present study sought to examine the vocabulary and morphological skills of a well characterized sample (i.e., confirmation of bilingual status, direct testing of NVIQ, detailed information concerning child language exposure to both languages) of school-age *bilingual* children with ASD in order to provide further empirical evidence that can inform the decisions of parents of children with ASD who are growing up in a bilingual context as well as the recommendations given by clinicians who work with this group of children.

Relationship between Amount of Language Exposure and Language Abilities

Multiple studies have been carried out with TYP monolingual and bilingual children in which the relationship between amount of language exposure and language acquisition has been investigated (e.g., Elin Thordardottir, 2011; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Pearson, Fernandez, Lewedeg, & Oller, 1997). Overall, these studies have shown that amount of language exposure is closely related to both vocabulary and morphological skills. For instance, in a large study with TYP Welsh-English bilinguals, Gathercole and Thomas (2009) found that vocabulary scores of school-age bilingual children (age range 7;0 to 11;0) were highly correlated with the input they received in each language. In fact, the authors reported that monolingual

Welsh children outperformed their bilingual counterparts in this measure and attributed this finding to the greater amount of Welsh exposure monolingual children had over their life. Similar results (i.e., monolingual children outperforming bilinguals on vocabulary measures) have been reported by other researchers in multiple languages (e.g., Elin Thordardottir, Rothenberg, Rivard, & Naves, 2006; Umbel & Oller, 1994).

Contrary to the TYP literature, to date, only one study (Hambly & Fombonne, 2014) has examined the relationship between amount of language exposure and language skills in bilingual children with ASD. In their study, Hambly and Fombonne examined different variables hypothesized to predict the development of lexical skills in the L2 of bilingually exposed children with ASD (i.e., current language exposure and language abilities in child's dominant language). Thirty-three bilingual children (mean age 5;0) were included in the study, although only 23 of them had some expressive vocabulary in their L2, as measured by parent report. Results demonstrated that current amount of language exposure accounted for more than 60% of the variance in L2 vocabulary, implying a crucial role for this factor. Though this is a logical relationship, it has often been assumed that children with ASD cannot pick up two languages; this evidence suggests that they can, given adequate exposure. However, what amount of exposure can be considered "adequate"?

This central question has been investigated in TYP bilingual children. In a carefully designed and detailed study with 5-year old French-English bilinguals, Elin Thordardottir (2011) established that when exposed to either of these languages 40% to 60% of the time, TYP bilingual children did not differ significantly from their monolingual peers on *receptive* vocabulary. Yet, a higher amount of exposure (> 60%) was required for bilingually-exposed children to exhibit comparable performance to monolingual children in the *expressive* domain. It can be hypothesized that similar patterns concerning amount of language exposure required to perform in the average monolingual range can be expected for bilingual children with ASD; however, this has not been investigated yet in this population. Although the sample size of the current study does not have the explanatory power to fully investigate this question in bilingual children with ASD, we nevertheless examined this question using an exploratory and descriptive approach in order to provide some empirical information for future studies.

As reported for TYP children (e.g., Pearson et al., 1997), and by Hambly and Fombonne (2014) in young bilingual children with ASD, amount of language exposure is a crucial predictor for language skills. Similarly, researchers in the field of ASD have reported that NVIQ and chronological age are also relevant factors for language skills in monolingual children with ASD (e.g., Anderson et al., 2007; Luyster et al., 2007). In addition, phonological memory has been found to be significantly correlated with lexical skills in TYP children (Gathercole, Service, Hitch, Adams, & Martin, 1999). Hence, we investigated the predictive value of these factors for the vocabulary and morphology scores of monolingual and bilingual children with ASD, with the aim of identifying the strongest predictors of dominant and L2 language skills. Data concerning the main predictive factors of bilingual language acquisition can help clinicians to focus on nurturing these abilities to favour dual language acquisition in children with ASD.

The Present Study

The purpose of the present study was to examine the vocabulary and morphological skills of school-age bilingual children with ASD. The specific research questions addressed were:

1). How do school-age bilingual children with ASD perform on standardized vocabulary and morphological tests relative to their monolingual ASD peers?

2). What is the contribution of current amount of language exposure, NVIQ, age, and phonological memory to variation in children's vocabulary and morphological skills?

Method

Participants

Seventy-seven school-age children participated in the present study. There were 47 TYP participants (age range 5;1 to 8;11 years) and 30 participants with ASD (age range 5;0 to 10;10 years). The study was conducted in Montreal, Canada, a multicultural city where French is the official language though many of the population also speak English. Participants were speakers of one or more of the following languages: French, English, or Spanish[1]. The majority of participants included in this study were exposed to some amount of French, thus this language was used to investigate effects of amount of language exposure. Participants' current amount of exposure (i.e., current exposure to a language in a typical week) to French ranged from 6% to 99%.

First, a subsample of eighteen carefully matched school-age children with ASD (9 monolingual and 9 bilingual) were compared on standard measures of vocabulary and morphology. Then, in a larger sample of children with different amounts of exposure to French (47 TYP, 30 ASD), we investigated the role of current amount of language exposure, as well as NVIQ, age, and phonological memory, in predicting language outcomes.

Typically-developing participants were recruited through flyers and from a university

[1] One bilingual participant with ASD spoke Russian and French. Given that the participant was clearly proficient in French and that this language was used in most contexts of her everyday life, scores from French tests were considered for analyses of dominant language, even though the history of language exposure and current amount of exposure to Russian was higher than that of French.

child research database. Participants with ASD were recruited from autism organizations, therapy clinics, schools, and a database from previous studies. Ethics approval was obtained from a university Institutional Review Board, and parent consent as well as child assent were obtained during the testing sessions. Children with ASD had a formal clinical diagnosis obtained from multidisciplinary teams at public hospitals or from licensed psychologists or psychiatrists. Furthermore, the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) was administered to parents of all participants as an additional source of confirmation of ASD and to rule it out in the TYP children. This questionnaire consists of 40 questions that provide information about different aspects of the child's early development, with a cut-off of 15 or higher being consistent with an ASD diagnosis. The SCQ is commonly used in research in the field of ASD and it is considered a useful tool to screen for ASD in school-age children (Chandler et al., 2007). As expected, SCQ scores were significantly higher in the ASD group than in the TYP group and confirmed the diagnosis of children in the ASD group, $t(74) = -13.689$, $p < .001$. While children were selected to be highly similar on NVIQ between groups and all were 5 to 10 years old, the ASD group was significantly older on average. Maternal education and gender distribution did not differ significantly between groups. Demographic characteristics of participants in both diagnostic groups are presented in Table 1.

Insert Table 1 about here

Inclusion criteria for the TYP group were the absence of learning, language, or developmental disorders; absence of physical, visual or hearing impairments; and absence of first- and second-degree family members diagnosed with ASD. For the ASD group, only high-functioning children (NVIQ > 80), who did not have any other medical condition associated with ASD (e.g., Fragile X) or any major physical limitation were included. Only verbal children with ASD were recruited, given the communication demands of the experimental tasks. However, some children with ASD who had language impairment (LI) were included in the study (n = 8) to reflect the heterogeneity of language abilities found in this population (Kjelgaard & Tager-Flusberg, 2001).

Bilingual status.

For the statistical analyses in which monolingual and bilingual children with ASD were compared to each other, *bilingual* children were defined as those who: 1) had a history or current exposure to an L2 greater than 20%, 2) obtained a proficiency score from their parents of 3 or 4 in both languages on a 4-point scale, 3) could complete the study protocol in both languages, and 4) obtained scores greater than 2 in both languages on a 4-point proficiency scale as rated by blind external judges using videos from the testing sessions. Only children who met the previously described criteria were retained in the bilingual group, regardless of age of first exposure to an L2 or varied language exposure patterns. Conversely, *monolingual* participants were those who: 1) had a history of exposure to an L2 of less than 20%, 2) obtained proficiency scores of 1 or 2 in their L2 as rated by parents, or 3) could not complete the experimental tasks in both languages.

To reflect the reality of bilingual experience (discussed in more detail below), children with varied histories of bilingual exposure were included in the study, rather than just those who had been exposed consistently to two languages from birth or very early in life. More specifically, given that the effects of age of acquisition of an L2 were beyond the scope of the present study, and our aim was to examine how *proficient bilingual* children with ASD (i.e., children who can communicate in both languages, regardless of language dominance) perform on standardized tests relative to monolingual children with ASD, bilingual participants with different ages of exposure to an L2 were included. In the bilingual group with ASD (n = 9), there were 7 simultaneous bilinguals (i.e., exposure to an L2 before 3 years of age) and 2 early sequential bilinguals (i.e., exposure to an L2 after 3 years of age but before age 5). In the TYP group (n = 47), 45 children were simultaneous bilinguals and 2 were early sequential bilinguals (age of exposure to an L2 before age 4).

Of interest, a number of children with ASD had grown up in different bilingual contexts. For instance, some of them were exposed early on to two languages (e.g., French and English). Yet, in some cases, this practice was discontinued when a diagnosis of ASD or ASD and language impairment was given, usually after the child was 2 or 3 years old. Most parents who discontinued use of both languages indicated that they were advised by clinicians to stop speaking both languages to their child, given that this could be too taxing and/or because they had to choose one language in which the child could receive intervention services. In cases where parents were proficient bilinguals (e.g., French-English), many followed this suggestion (e.g., choosing French) and a child who was being raised as bilingual became monolingual (i.e., only able to interact in one language). However, in some of these cases, the extended family, caregivers, or friends were not proficient in the language chosen by the parents and, therefore, they continued to interact with the child in the language dropped by the parents (e.g., English). Thus, the child continued to communicate, although to a lesser extent, in both languages.

In other cases, parents were advised to drop one language (typically the home language) and to communicate with their child in the language of the community (i.e., French), with the aim of having more access to therapy programs and later on to the school system. This change from bilingual to predominantly monolingual exposure was possible when caregiver couples included one parent who spoke the community language (e.g., French) and another who spoke both a minority (e.g., Spanish) as well as the community language. Nevertheless, when both parents were native speakers of a minority language, many of them continued to communicate in this language with their child for different reasons (e.g., lack of proficiency in the community language, desire for their child to be able to communicate with other family members, etc.), while the child was acquiring the community language from daycare or caregivers. Consequently, early language exposure to two languages did not guarantee bilingual proficiency for some children with ASD, although in other cases, even when one language was prioritized, it did.

Based on the previously discussed context, the determination of bilingual status in the present study showed an interesting outcome, in which not all children with ASD who had language exposure to an L2 were proficient bilinguals. First, 30 potential bilingual children with ASD were recruited to take part in the study. Twenty-six children had histories of language exposure (i.e., language exposure over their lifetime) to an L2 greater than 20% and four were reported as bilinguals by their parents, although their history of language exposure to an L2 was less than 20%. However, these four children's current language exposure was greater than 20%. From these 30 potential bilinguals, 8 did not undergo formal testing in their L2 since parents reported that the child's proficiency in their L2 was limited or that the child understood but did not speak the L2. In addition, 2 children were not able to come to the second session in which the L2 was assessed, thus, confirmation of bilingual status was not possible. Therefore, 20 children were tested in both of their languages, yet 5 of them were not proficient enough in their L2 to complete the testing protocol (receptive bilinguals). Finally, from the 15 proficient bilingual children, 2 were outliers (1 child with NVIQ > 160 and another who had received a diagnosis of intellectual disability), 2 had missing data and 2 could not be matched with any of our monolingual participants. Accordingly, for the group comparison analyses only 9 proficient bilingual children with ASD were included.

Procedure

This study was part of a larger project examining the cognitive and linguistic abilities of bilingual and monolingual children with ASD. Monolingual participants in both diagnostic groups were assessed in one session lasting approximately 2 hours, while bilingual participants completed two sessions approximately two weeks apart, one in their dominant language and one in their other language. Participants' dominant language was either French or English; this had been determined by participants' self-report, parent report, and by the child's history of language exposure. For correlation and regression analyses, we report only French measures because most of the participants had some exposure to French.

NVIQ was examined using the Leiter-R (Roid & Miller, 1997), a nonverbal test that can be used with children from different language backgrounds as well as with children who have developmental disabilities. To assess phonological memory, the number repetition subtest from the CELF-CDN F or its English version (CELF-4; Semel, Wiig, & Secord, 2003) was administered in the participant's dominant language[2]. Children were tested in a quiet research lab at a university or at the participants' home.

Parents were asked to fill out questionnaires concerning their child's communication abilities and behaviours, including their history of language exposure (described in more detail below) and the child's early social communication behaviors (SCQ). Information on parental education (i.e., highest academic degree attained) was also gathered as a proxy for socio-economic status. Trained research assistants who were native speakers of each of the languages

[2] Participants' dominant language was either English or French, but not Spanish. This, given that they were attending French or English schools and spoke this language with friends and in other social contexts.

of interest (i.e., French, English, or Spanish) administered the tasks to the participants. Breaks and snacks were provided as needed during the assessment, and participants received a small gift at the end of each session as a token of appreciation for their participation.

Measures.

The following measures were used to examine the children's language background, phonological memory, and language abilities:

Child Language Exposure Questionnaire (Gonzalez-Barrero & Nadig, 2013; see Appendix). This questionnaire was developed based on variables considered central for the assessment of language background, as discussed in Elin Thordardottir, Rothenberg, Rivard, & Naves (2006) and Elin Thordardottir (2011), as well as on advice from an expert in the field of bilingual language development (F. Genesee, personal communication, October 25, 2013). Trained research assistants conducted this interview in person with the child's parents; it lasted approximately 15 minutes. The questionnaire consisted of different sections: 1) The first part included questions about the child's *current language use in different contexts* with respect to the languages of exposure, such as "*What language(s) does the child use when speaking with friends?*" *and* "*In what language(s) does the child watch television?*". The approximate number of times the child read per week, regardless of language, was also documented as a measure of literacy. 2) An estimate of the *current total number of hours of exposure per week to each language* was then calculated. Parents reported the amount of exposure to each language per day during a typical weekday and the weekend, excluding hours when the child was asleep. Parents were encouraged to consider all settings when making these reports (e.g., home, school, sport classes, etc.). 3) In the third section, information concerning the *child's language history was gathered from birth until current age.* Parents were asked about the child's age of first exposure to each language along with questions concerning the child's patterns of exposure year by year (e.g., from birth to 12 months, 1 to 2 years, etc.). A percentage of exposure per year was then calculated and an average across total years of life was obtained for each language. 4) The *child's current proficiency* in each language was estimated by the parent on a 4-point scale (i.e., From 1 = Limited to 4 = Excellent), separately for listening and speaking skills. 5) Finally, parents were asked to report any relevant events concerning their child's language exposure that was not previously mentioned (e.g., "*switch from French/English to mostly English for speech therapy from age 4 onwards"*).

Échelle de vocabulaire en images Peabody (ÉVIP; Dunn, Thériault-Whalen, & Dunn, 1993). Vocabulary skills were assessed using the Peabody Picture Vocabulary Test in English (PPVT-4; Dunn & Dunn, 2007), French, and Spanish (Test de Vocabulario en Imagenes Peabody-TVIP; Dunn, Padilla, Lugo, & Dunn, 1986), as appropriate. This is a standardized test in which the examiner names an object, action, or person and the participant is asked to select the corresponding picture from an array of four options. Standard scores were used for statistical analyses.

Évaluation clinique des notions langagières fondamentales – Version pour francophones du Canada (CELF CDN-F; Secord et al., 2009). Three subtests from the French, the English (CELF-4; Semel, Wiig, & Secord, 2003), and the Spanish version (CELF 4 Spanish Edition; Wiig, Semel, & Secord, 2006) of the Clinical Evaluation of Language Fundamentals were used to measure morphological abilities, phonological memory, and to identify language impairment. In the word structure (*morphologie)* subtest, the child is asked to complete sentences using a specific morphological form (e.g., prepositions, plural, reflexive pronouns, etc.) prompted by the experimenter (e.g., "*This is a book, here there are two ____"*). The French version of this subtest consists of 35 items, while the English version includes 32 items, and the Spanish 29. Raw scores are calculated (1 = correct response, 0 = incorrect response) and then a scaled score can be derived based on the child's age. The scaled score from this subtest was used as a measure of morphological proficiency.

To examine phonological short-term and working memory skills, the number repetition (*répétition de nombres*) subtest from the CELF was administered. This test includes two tasks: first, children are asked to repeat verbatim a series of numbers of increasing length (i.e., number repetition forward). Afterwards, participants have to repeat backwards the numbers said by the experimenter (i.e., number repetition backwards). While the former task provides information about the child's short term memory, the latter is considered a measure of working memory (Engel de Abreu, 2011). Given age differences among the participants, the scaled score of number repetition backwards was used as a measure of phonological working memory in the participant's dominant language.

Language impairment (LI) was determined via the recalling sentences (*repetition de phrases*) subtest from the CELF CDN-F. In this subtest, the child is prompted to repeat sentences (32 items) of increasing complexity that are first modeled by the experimenter. Responses are scored in relation to the number of errors made in each sentence and a scaled score is computed based on the child's chronological age. Sentence repetition is considered an accurate marker for LI (Conti-Ramsden, Botting, & Faragher, 2001), with a cutoff of -1SD showing adequate sensitivity and specificity for the identification of LI (Elin Thordardottir et al., 2011). Although none of the current research questions pertained to LI, it was important to characterize what proportion of participants with ASD presented with LI for the analyses conducted.

Data Analyses

Conceptualization of bilingualism. The research questions examined in the present study required two different operational definitions of bilingualism. First, group comparisons of language abilities necessitated a dichotomous approach distinguishing between monolinguals and bilinguals; the operational definition of monolingual and bilingual was given earlier. Second, investigations of the relationship between amount of language exposure and language proficiency required a continuous approach; hence all children were included in one regression model and current amount of exposure[3] to French was used as a predictor variable.

Statistical Analyses

The performance of the bilingual children with ASD relative to their monolingual peers on vocabulary and morphology measures was examined with a series of *t*-tests. Following Paradis (2011), standard scores were used to control for chronological age, given the age range of the participants in the current study and also considering that age was entered as a predictor in the regression analyses.

To investigate the relationship between amount of language exposure and language proficiency, Pearson's correlations were first conducted between current amount of language exposure and scores from the standardized tests. In addition, multiple regression analyses were performed to examine the contribution of predictors that have been reported to account for significant amounts of variance in vocabulary and morphological skills in TYP bilingual children, as well as factors reported to be predictive of language skills in monolingual children with ASD. Specifically, the following predictor variables were entered into the regression

[3] Current language exposure and history of language exposure were highly correlated in our data (r = .85). Given previous findings in the TYP bilingual literature (Bedore et al., 2012) as well as on bilingual children with ASD (Hambly & Fombonne, 2014), we focus on current amount of language exposure in the present study for data analyses.

analyses: current amount language exposure, NVIQ, age, and phonological working memory. Children with and without LI were included for these analyses.

Results

Group Comparisons

For analyses comparing the language skills of the bilingual and monolingual children with ASD, we only included *proficient bilingual* children between 5 to 9 years of age (i.e., children who met the criteria of proficient bilingualism previously described in *bilingual status* section). Only 9 bilingual participants (6 French dominant and 3 English dominant) with ASD met these criteria and were, thus, included. Nine monolingual children with ASD, who were close matches on several variables to the bilingual children with ASD, were also included in these analyses. Since the focus of the present study was on bilingual children with ASD, we did not include TYP participants for this set of analyses, given that some of the children with ASD had concomitant LI and comparison to TYP children without LI was not appropriate. In addition, it was not possible to match on all necessary factors (e.g., dominant language, amount of language exposure) for a full 2 diagnostic group x 2 language status (bilingual vs. monolingual) investigation of language measures in this sample.

Bilingual children with ASD (mean age 7;11 years) were closely matched to monolingual children with ASD (mean age 7;10 years) on age, NVIQ, maternal education, and, to the extent possible, dominant language. There were no significant differences in the groups' scores on the SCQ or with respect to gender. Demographic information is provided in Table 2. Two children with ASD and LI were included in each group, to reflect the heterogeneity of language abilities in this population (Kjelgaard & Tager-Flusberg, 2001; Tager-Flusberg, 2015).

Insert Table 2 about here

Vocabulary. A *t*-test was conducted with this subset of participants (9 monolinguals with ASD and 9 bilinguals with ASD) to examine vocabulary scores in their dominant language – either French or English; Spanish was never a dominant language and thus scores on the Spanish vocabulary test are not reported here. There were no outliers, as assessed by inspection of a boxplot. Vocabulary scores for each ASD group were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), and there was homogeneity of variances, as assessed by Levene's test ($p = .99$).

Results revealed that, although both groups performed within the average range (M = 100, SD = 15) on the PPVT-4 or the EVIP, there was a marginally significant difference, $t(16) = 1.79$, $p = .092$, $d = .84$, where monolingual children with ASD exhibited significantly higher scores (M = 111, SD = 20.65) compared to the bilingual children with ASD (M = 95, SD = 17.09).

Insert Figure 1 about here

Morphology. Concerning morphological skills, we conducted a *t*-test to examine whether scaled scores from the morphology subtest of the CELF (M = 10; SD = 3), in the dominant language, differed for the ASD groups depending on language status. The assumptions of normality, homogeneity of variance, and no outliers were met. Results showed no statistically significant differences between the monolingual (M = 8, SD = 3.35) and bilingual participants with ASD (M = 7, SD = 3.23), $t(16) = .645$, $p = .528$, $d = .30$. Individual scores for vocabulary and morphology measures in the participant's dominant and non-dominant language are presented in Tables 3 and 4.

Insert Figure 2 about here

Insert Table 3 about here

Insert Table 4 about here

Predictors of Language Skills

As previously discussed, to examine the relationship between language performance and amount of language exposure in both diagnostic groups (i.e., TYP and ASD), as well as to increase statistical power, the complete sample (n = 77) was included in regression analyses investigating the best predictors of language abilities. Separate analyses for vocabulary and morphology measures are described below.

Vocabulary.

Correlation Analysis. A Pearson's correlation was run to assess the relationship between current amount of language exposure and lexical proficiency, as measured by the EVIP standard score, for each diagnostic group (i.e., TYP and ASD). Results revealed that, as expected, there was a strong positive correlation between these two variables for TYP children, $r(45) = .70$, $p <$

.001. Similarly, the Pearson's correlation for the ASD group showed a strong significant correlation between current amount of language exposure and EVIP standard scores, $r(28) = .74$, $p < .001$. To examine whether these two correlations were significantly different in TYP children and in ASD, a Fisher's z-transformation was used and a calculation of the difference between these correlations was performed. Results showed that the two correlations were not significantly different from each other ($p = .73$). Correlations between EVIP scores and current amount of language exposure for each diagnostic group are presented in figure 3.

Insert Figure 3 about here

Regression Analysis. To further investigate the strongest predictors of vocabulary skills in TYP children and in children with ASD who have different amounts of language exposure to French, a multiple linear regression using the *enter* method was conducted. The predictors entered in the analysis were: current amount of language exposure (percentage of current exposure to French), chronological age, NVIQ (standard score from the Leiter-R), phonological working memory (scaled score from the CELF number repetition backwards subtest), and diagnosis (TYP or ASD). The assumptions of multiple regression were evaluated. There was linearity as assessed by a plot of studentized residuals against the predicted values and by partial regression plots. A Durbin-Watson test statistic of 2.09 showed independence of residuals. In addition, other assumptions required for multiple regression (e.g., no multicollinearity, normality, homoscedasticity, etc.) were met.

The full model explained a significant amount of variance in the EVIP scores, $F\,(5,71) = 36.971$, $p < .001$, $R^2 = .722$ $R^2_{Adjusted} = .703$. The analysis revealed that current amount of language exposure, phonological working memory, and diagnosis were all significant predictors of vocabulary skills, $p < .05$. The strongest predictor in this model was current amount of language exposure, which accounted for 62% of the variance in vocabulary skills. Diagnostic group had a significant negative weight in this model, indicating that, after accounting for the other variables, children with ASD performed lower on vocabulary scores, relative to TYP children. NVIQ and chronological age did not significantly predict vocabulary scores. Regression coefficients and standard errors can be found in Table 5.

Insert Table 5 about here

Morphology.

Correlation Analysis. As was done for vocabulary skills, a Pearson's correlation was carried out to examine the relationship between current amount of exposure to French and morphology scores for each diagnostic group. A significant correlation was found between current amount of language exposure for TYP children, $r(45) = .55$, $p < .001$, as well as for children with ASD, $r(28) = .58$, $p = .001$. After a Fisher's z-transformation was computed to calculate the difference between these correlations, results revealed that correlations for TYP children and children with ASD were not significantly different ($p = .86$). Figure 4 depicts the correlation between morphology scores and current amount of language exposure for both groups.

Insert Figure 4 about here

Regression Analysis. A multiple regression analysis using the method *enter* was conducted to investigate which factors (i.e., current amount of language exposure, chronological age, NVIQ, phonological working memory, and diagnostic group) predicted variation in morphology scores. The different assumptions of multiple regression were assessed and met. Results showed that there was linearity, independence of residuals (Durwin-Watson = 1.7), as well as homoscedasticity as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. There was also absence of multicollinearity, as assessed by tolerance values greater than 0.1., absence of outliers as well as absence of highly influential points, and no leverage values greater than 0.2. Finally, the assumption of normality was met as assessed by a Q-Q Plot.

Results indicated that the model explained a significant amount of the variance in morphology scores, $F(5,71) = 22.274$, $p < .001$, $R^2 = .611$ $R^2_{Adjusted} = .583$. The analysis demonstrated further that current exposure, age, phonological working memory, and diagnostic group were significant predictors of the morphology scores, $p < .05$. NVIQ was not a significant predictor. Similar to the results for vocabulary skills, current amount of language exposure was the strongest predictor of morphological abilities, accounting for 49% of the variance in the model. Importantly, diagnostic group was a significant negative predictor, indicating that children in the ASD group tended to perform lower than those in the TYP group. Regression coefficients for morphology scores are presented in Table 6.

Insert Table 6 about here

Discussion

Using direct assessment of language abilities, we examined the performance of school-age bilingual children with ASD on vocabulary and morphology measures relative to that of their monolingual peers with ASD. In addition, we investigated the predictive role of current amount of language exposure for language learning in both bilingual and monolingual children with ASD. Our findings revealed that bilingual children performed in the average monolingual range (i.e., based on the test norms) on both standardized language tests in their dominant language. However, the monolingual children with ASD tended to outperform the bilingual group with ASD on vocabulary measures. Statistical results for the morphological subtest were not significantly different.

On the one hand, results from our group comparisons (i.e., tendency of monolingual children to perform better than bilingual children) are in line with findings from the typically-developing literature (e.g., Gathercole & Thomas, 2009; Bialystok, Luk, Peets, & Yang, 2010). For instance, in a large sample of children (n = 1738), Bialystok and colleagues (2010) found that bilingual children exposed to English and other languages (age range 3 to 10 years) scored consistently below their monolingual English peers at all ages on the PPVT, when only one language of the bilingual children was assessed. Nevertheless, bilingual children's scores were within the average range on this test.

On the other hand, findings from the present study differ from results reported with younger bilingual children (i.e., before age 6) with ASD. Previous studies on bilingualism in children with ASD did not find significant differences between monolingual and bilingual groups in early language development (e.g., Hambly & Fombonne, 2012; Ohashi et al.., 2012; Petersen et al., 2012; Valicenti-McDermott et al., 2013). However, our results, in a small but very well-characterized sample of school-aged children with ASD, revealed marginally significant statistical differences where monolinguals outperformed bilinguals on vocabulary scores. These discrepant findings can be reconciled when taking into consideration the populations as well as the methodological approaches used here relative to other studies.

First, one possible explanation for the differences in findings from previous research and the current study might lie in the chronological age of the groups studied. Our participants were school-aged children between 5 to 9 years of age, whereas most of the past studies in this field have focused on toddlers and pre-school age children. While monolingual and bilingual children with ASD have been reported to reach very early language milestones, such as babbling (Valicenti-McDermott et al., 2012) and first words (Hambly & Fombonne, 2012) at a similar age, children's language complexity increases during the school years. This provides the opportunity to study more advanced aspects of the structural composition of language, which cannot be observed at early stages of language development.

Another possible reason for the discrepancy between our results and previous findings is the methodological approach selected to examine language skills. In the current study, we used direct assessment of vocabulary and morphological abilities, whereas other studies (e.g., Reetzke et al., 2015) with pre-school children have used parent questionnaires (e.g., Children's Communication Checklist-2, Bishop, 2006). Although such questionnaires provide valuable information concerning children's' language skills at early ages, direct assessment offers a more in depth and precise account of the child's specific abilities on different language domains at later ages.

Moreover, as previously discussed, various studies have examined the language skills of *bilingually exposed* children with ASD. Whether these children are active users of the languages they are exposed to is usually not described. Receptive bilingualism is different from productive bilingualism (Beardsmore, 1982) and it is possible that, at early ages, *bilingually exposed* children's language skills do not differ significantly from those of their monolingual peers with ASD. To accurately interpret research findings regarding the language abilities of bilingual children with ASD, it is critical that researchers thoroughly describe the characteristics of their samples to fully understand the backgrounds of the bilinguals being studied. In the present study, we used a multifactorial approach to define bilingualism (i.e., parent questionnaires, direct assessment of bilinguals' two languages and scores from external judges) and only included children who, even if they had a dominant or preferred language, were able to communicate in two languages. Of interest, we found that early language exposure to two languages alone did not necessarily result in proficient bilingualism in school-age children with ASD given different factors (e.g., need to prioritize one language to receive intervention services). This is a relevant point to be taken into consideration for researchers as well as clinicians. A comprehensive documentation of the languages the child has been exposed to during his/her life as well as the current amount of language exposure, are background measures that provide insight into the child's language abilities. However, direct assessment of the child's language skills is needed to have a better account of the language profile of bilingual children with ASD and their specific strengths and needs in each of their languages.

Returning to the question presented at the beginning of this paper, can children with ASD become bilingual? Our findings suggest that some children with ASD are able to understand and use two languages, although their abilities will depend significantly on the amount of language exposure they have in each of their languages. In the present study, the bilingual children with ASD performed within the average range on vocabulary and morphology tasks in their dominant language. Therefore, the advice to limit the languages a child with ASD is exposed to, given concerns about the negative impact of bilingualism on child's language skills, does not have empirical support. The interaction between children with ASD and their caregivers early in life has been reported to influence children's communication skills later in life (Siller & Sigman, 2002), hence, parents as well as children on the autism spectrum should have the choice of choosing the languages they want to use to communicate with each other. In addition, the number of languages a person speaks is an important factor for career choices and job opportunities. For instance, one of the parents of our participants stated that he wanted to raise his child bilingual (English-French), but did not follow this path because of suggestions of some health professionals when the child was an infant. Accordingly, the child currently speaks only English. This parent expressed concerns about the possible difficulty for his child to find a job later in life as well as his educational opportunities, given the child's lack of French proficiency in a province where this language is the majority one. Therefore, bilingualism has practical implications for the educational and professional attainment of children with ASD later in life.

Nonetheless, it is important to highlight that in this study not all the children with ASD who were exposed to two languages at different points in life became proficient bilinguals. As previously described, from 30 potential bilingual children, only 15 were able to communicate in both of their languages. Some of the 15 children who were not classified as proficient bilinguals understood the L2 but did not speak it, as reported by parents and confirmed in some cases by direct testing. Indeed, some of these receptive bilingual children had histories of language exposure of almost 40% to an L2, yet they were not able to communicate in that language. In contrast, some children in the proficient bilingual group had exposures of 30% to an L2 over their lifetime and could maintain a conversation in this language. These results reveal the heterogeneity of language outcomes for bilingually exposed children with ASD. Accordingly, more research is needed to understand the specific factors, beyond language exposure, that lead to proficient bilingualism in children with ASD.

Concerning the second question of interest in this study, we found that current amount of language exposure was the strongest positive predictor of vocabulary and morphological skills for TYP children as well as for children with ASD. In addition, phonological working memory and diagnostic group were significant predictors of both vocabulary and morphology skills, while age was a significant predictor of morphology only. These findings corroborate those reported by Hambly and Fombonne (2014) demonstrating the important relationship between amount of language exposure and language proficiency in children with ASD. Furthermore, they support the claim that vocabulary is highly dependent on amount of language exposure (Hart & Risley, 1992; Hoff et al., 2012; Huttenlocher et al., 1991; Pearson et al., 1997; Elin Thordardottir, 2011), while child's internal characteristics such as maturation (as reflected by age), may also be important for the development of morphological skills (Paradis, 2011).

This study is the first to investigate the relationship between amount of language exposure and performance on vocabulary and morphology tests in monolingual and bilingual children with ASD. We found a similar correlation between amount of language exposure and language proficiency on these measures in TYP children and children with ASD. In addition, it was observed in our correlation analyses (see figure 3) that after reaching 40% of exposure to French, children with ASD (without LI) tended to perform at or above the average range on the EVIP. However, to perform in the average range on the CELF morphology subtest (see figure 4), children with ASD (without LI) needed approximately 60% of current amount of exposure to French. These results are similar to those reported for TYP bilingual children (e.g., Elin Thordardottir, 2011). Although establishing the relative amount of exposure required for the ASD group to perform within the average range on standardized tests requires a larger sample size, this is an empirical observation that needs further study given its clinical implications. That is, if a bilingual child with ASD has attained the expected levels of exposure to develop functional proficiency in his or her L2 and still is not able to communicate in that language, further investigations might be conducted to explore other factors (e.g., presence of LI, lack of identification with the language, etc.) that lead to that outcome.

Although this study provides new insight into the language abilities of bilingual children with ASD as well as into the role of current amount of language exposure and language proficiency in this population, our sample size was relatively small, and studies with more participants need to be conducted to replicate our results. However, proficient bilingual children with ASD are a very specific population and recruitment and assessment of these children entail significant efforts. In addition, it is central to note that these results were found in a subsample of high functioning bilingual children with ASD, who live in a context in which bilingualism is highly valued and supported. Thus, findings from this study need to be interpreted taking into consideration the specific characteristics of our sample and their community context. Furthermore, while the age range of participants in this study is narrower than that used in other studies that have examined language skills in ASD (e.g., 4 to 14 years-olds, Kjelgaard & Tager-Flusberg, 2001), it still spanned a number of years (5 to 9) where the attainment of language skills may differ. We controlled for this variable using standardized tests, which account for the child's age, and chronological age was also included in our regression models as a predictor; however, future studies need to address the previously cited limitations. Finally, other language skills such as syntax and phonology need to be studied in bilingual children with ASD and findings need to be replicated in other language combinations to better inform the language characteristics of children with ASD who are developing two linguistic systems.

Conclusion

In the present study, we examined the vocabulary and morphological skills of a group of school-age proficient bilingual children with ASD relative to their monolingual ASD counterparts. In addition, we investigated the predictive role of current amount of language exposure for language proficiency in these measures. Findings revealed that bilingual children with ASD performed within the average range on standardized tests of vocabulary and morphology in their dominant language, although there was a tendency for monolingual children with ASD to outperform the bilingual group on vocabulary scores, consistent with findings reported in the bilingual typically-developing literature. Furthermore, current amount of language exposure was the strongest predictor for these measures. Other factors, such as child's phonological memory, also contributed to language performance in our models.

What are the implications of these findings for children with ASD who are growing up in bilingual environments? In line with previous findings, results from this study support the claim that some children with ASD are capable of acquiring two languages when provided with optimal opportunities to do so (e.g., approximately 50% or more exposure to have language skills in the average range). In fact, our bilingual participants with ASD completed multiple receptive and expressive linguistic tasks in both of their languages during our research protocol and they were able to communicate with others in their two languages. Accordingly, results showed that bilingualism is possible for children with ASD.

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Tables

Table 1. Demographic Characteristics of the Full Sample by Diagnostic Group

Variable	**TYP Group** (n = 47) *M (SD)*	**ASD Group** (n = 30) *M (SD)*	***p* value**
Chronological age in months	85 (13.62)	94 (17.53)	.02
NVIQ	111 (10.78)	110 (12.13)	.58
SCQ	4 (3.05)	20 (5.96)	.00
Maternal Education	16 (2.03)	15 (2.53)	.16
Gender	35 Male	27 Male	.09
	12 Females	3 Female	

Note. TYP = typically-developing group; ASD = autism spectrum disorders; NVIQ = Nonverbal IQ; SCQ = Social Communication Questionnaire.

Table 2. Demographic Characteristics and Matching of Subset of Children with ASD for Group Analyses

Variable	**Monolingual ASD** (n = 9) *M* *(SD)*	**Bilingual ASD** (n = 9) *M* *(SD)*	***p* value**
Chronological age in months	95 (14.83)	94 (14.83)	.83
NVIQ	110 (8.54)	108 (10.42)	.63
SCQ	18 (5.45)	20 (3.27)	.47
Maternal Education	16 (1.79)	15 (3.33)	.49
Gender	9 Male 0 Females	7 Male 2 Female	.21
Dominant Language	6 French 3 English	7 French 2 English	.63
Current Amount of Exposure to L1	88% (6.67)	66% (20.04)	.01

Note. ASD = autism spectrum disorders; NVIQ = Nonverbal IQ; SCQ = Social Communication Questionnaire; L1 = dominant language.

Table 3. Individual Scores in Dominant Language of Children with ASD by Language Group

Participants with ASD	**Dominant Language (L1)**	**History of Exposure to L1**	**Current Exposure to L1**	**Vocabulary L1 (Standard Score)**	**Morphology L1 (Scaled Score)**
Monolingual					
M1	French	84%	91%	85	9
M2	French	100%	96%	118	10
M3	French	100%	97%	112	8
M4	French	90%	85%	128	10
M5	French	78%	97%	145	12
M6	French	60%	93%	111	5
M7	French	80%	84%	126	12
M8*	English	84%	90%	84	2
M9*	English	96%	81%	94	6
Bilingual					
B1	French	21%	47%	120	11
B2	English	58%	58%	95	5
B3	French	70%	80%	100	10
B4	French	72%	77%	84	5
B5	French	37%	45%	90	6
B6	English	68%	91%	106	10
B7	French	61%	94%	115	11
B8*	French	50%	43%	65	3
B9*	English	61%	59%	84	4

Note. ASD = autism spectrum disorders; L1 = dominant language; B = bilingual; M = monolingual. Some monolingual participants were exposed to a second language; however, they were not proficient in that language.

*Participants with language impairment.

Table 4. Individual Scores in Non-Dominant Language of Bilingual Children with ASD

Bilingual Participants with ASD	**Non-Dominant Language (L2)**	**History of Exposure to L2**	**Current Exposure to L2**	**Vocabulary L2 (Standard Score)**	**Morphology L2 (Scaled score)**
B1	Russian	79%	53%	-	-
B2*	French	42%	37%	60	3
B3	English	30%	20%	81	3
B4*	English	24%	20%	83	4
B5*	Spanish	60%	45%	92	1
B6	French	32%	9%	100	7
B7	English	39%	6%	73	1
B8	English	50%	57%	78	2
B9*	Spanish	36%	40%	99	6

Note. ASD = autism spectrum disorders; L2 = non-dominant language; B = bilingual. For participant B1, L2 was not assessed because equivalent Russian measures were not available.

*Participants had a history of exposure or a current exposure to a third language of less than 10%.

Table 5. Summary of Multiple Regression Analysis for Vocabulary Skills

Variable	***B***	***SE_B***	**Beta**	***t***	***P***
(Constant)	14.45	18.36		.79	.434
Current Exposure	.61	.06	.62	9.62	.000
Chronological age	.20	.11	.12	1.80	.076
NVIQ	.22	.15	.09	1.40	.166
Working memory	1.88	.66	.20	2.84	.006
Diagnostic Group	-19.00	3.70	-.35	-5.14	.000

Note. *B* = unstandardized regression coefficient; SE_B = standard error of the coefficient; Beta = standardized coefficient; NVIQ = nonverbal IQ.

Table 6. Summary of Multiple Regression Analysis for Morphological Skills

Variable	***B***	***SE_B***	**Beta**	***t***	***P***
(Constant)	-7.71	3.22		-2.40	.019
Current Exposure	.07	.01	.49	6.46	.000
Chronological age	.06	.02	.23	2.91	.005
NVIQ	.03	.03	.09	1.21	.230
Working memory	.37	.12	.26	3.21	.002
Diagnostic Group	-2.62	.65	-.33	-4.04	.000

Note. *B* = unstandardized regression coefficient; SE_B = standard error of the coefficient; Beta = standardized coefficient; NVIQ = nonverbal IQ.

Figures

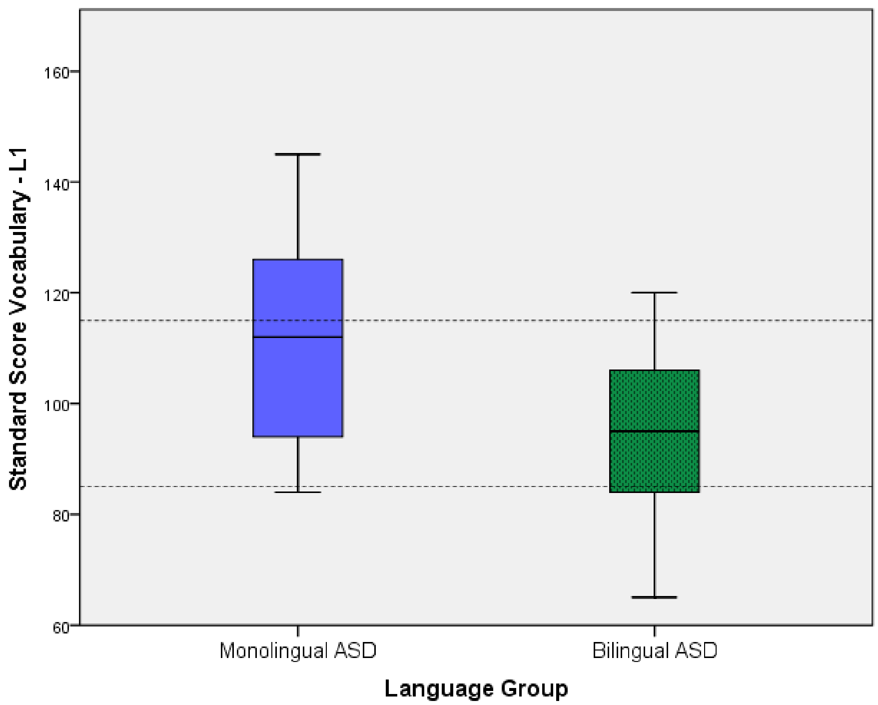

Figure 1. Boxplots of vocabulary scores from participants' dominant language by language group. ASD = autism spectrum disorders; L1 = dominant language. Dotted lines represent average range on standardized test.

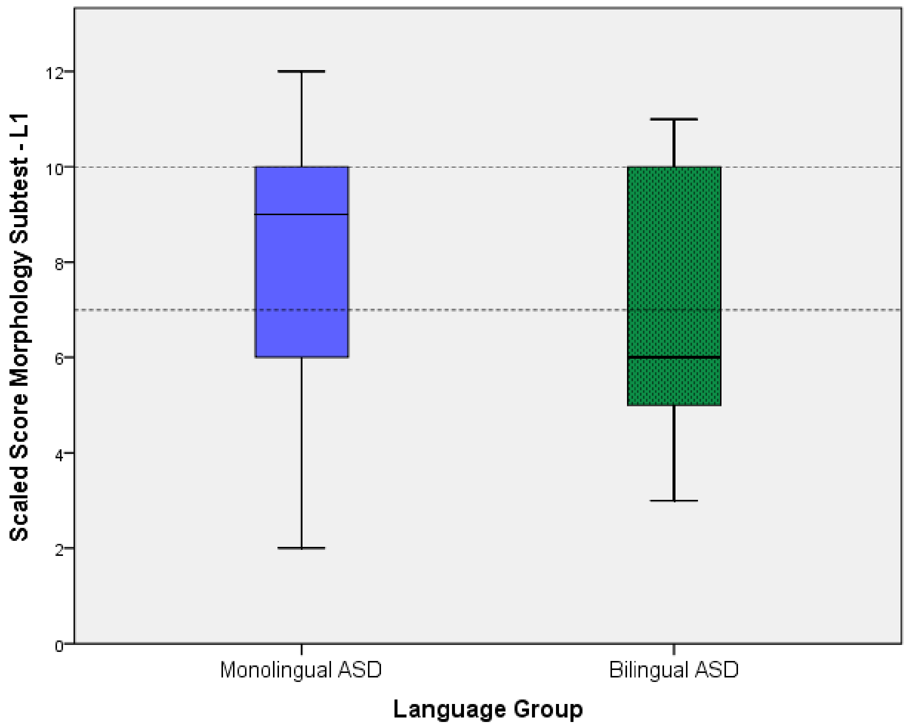

Figure 2. Boxplots of morphology scores from participants' dominant language by language group. ASD = autism spectrum disorders; L1 = dominant language; CELF = Clinical Evaluation of Language Fundamentals. Dotted lines represent average range on scaled score of the CELF.

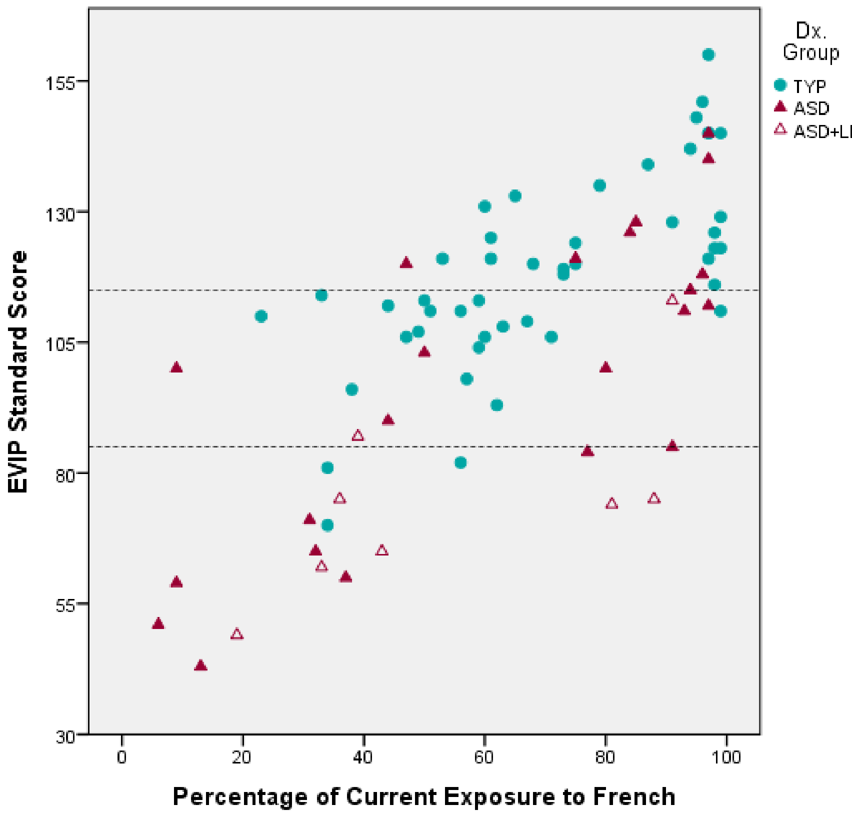

Figure 3. Correlation between amount of language exposure and vocabulary scores. EVIP = Échelle de vocabulaire en images Peabody; TYP = typically-developing group; ASD = autism spectrum disorder group; ASD+LI = participants with autism spectrum disorders and concomitant language impairment (included for illustrative purposes, not a separate group in analyses). Dotted lines represent average range of performance on EVIP.

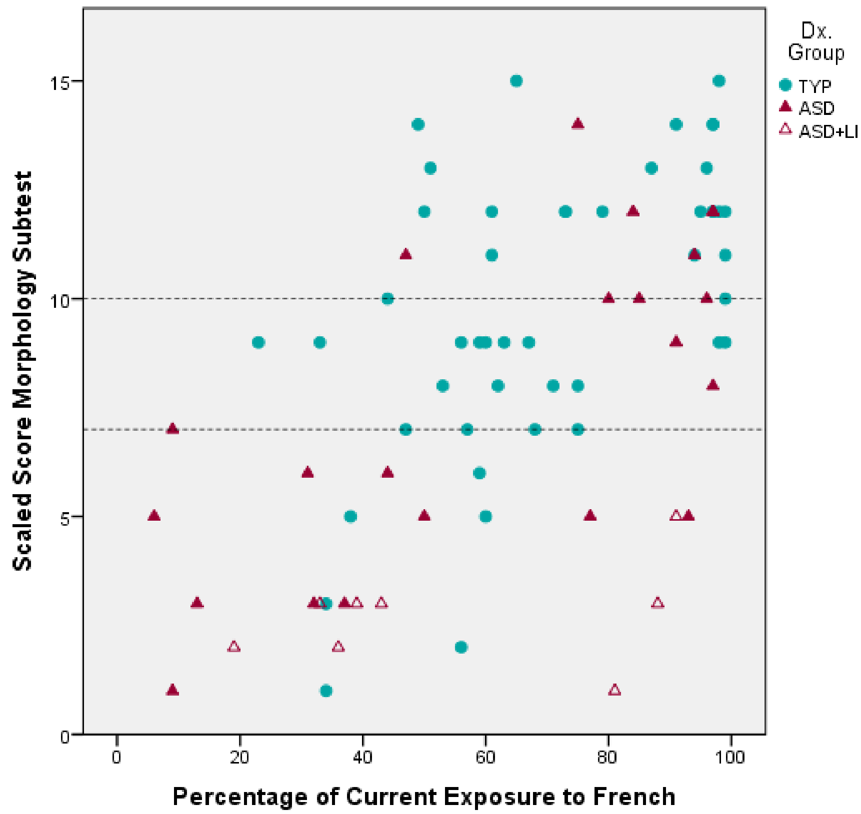

Figure 4. Correlation between amount of language exposure and performance on the CELF. CELF = Clinical Evaluation of Language Fundamentals; TYP = typically-developing group; ASD = autism spectrum disorder group; ASD+LI = participants with autism spectrum disorders and concomitant language impairment (included for illustrative purposes, not a separate group in analyses). Dotted lines represent average range of performance on the CELF.

Preface to Study 2

Study 1 examined the language skills of proficient bilingual children with ASD relative to their monolingual peers with ASD. Findings revealed that the monolingual group with ASD outperformed the bilingual group with ASD on a standardized vocabulary measure. However, the bilingual group scores were within the average range on the PPVT. No significant differences were found on morphology scores between bilingual and monolingual children with ASD using the CELF-4. In addition, regression analyses showed that current amount of language exposure was the strongest predictor of both vocabulary and morphology scores, mirroring results reported in the typical-developing bilingual literature (Hoff et al., 2012).

Results from Study 1 suggest that, when provided with appropriate opportunities, children with ASD can become bilingual. Since bilingualism is possible in this population, we decided to go further and test whether cognitive advantages reported in typically-developing bilingual children can also be found in bilingual children with ASD. Given the characteristic difficulties in set-shifting (Hughes, Rusell, & Robbins, 1994) and generativity (Dichter, Lam, Turner-Brown, Holtzclaw, & Bodfish, 2009) in individuals with ASD, these executive functioning skills present the perfect scenario to test the bilingual advantage hypothesis (Kroll & Bialystok, 2013). Accordingly, Study 2 used a paradigm that involves lexical-semantic abilities along with executive functioning skills to test this hypothesis. In addition, the second aim of Study 2 was to investigate if the strategies used by TYP children to perform this task are similar to those exhibited by children with ASD (e.g., amount of switches between categories during the task), providing further evidence concerning the cognitive strategies used by children on the autism spectrum to perform cognitive paradigms.

5. Manuscript 2

Verbal fluency in bilingual children with Autism Spectrum Disorders

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ABSTRACT

We examine the impact of bilingualism on verbal fluency, a paradigm that relies on executive functioning and lexical-semantic skills. Four groups of school-age (5 to 10 years-old) children participated in the study: 13 Typically-developing (TYP) monolingual children, 13 TYP bilingual children, 13 monolingual children with Autism Spectrum Disorders (ASD) and 13 bilingual children with ASD. Participants were matched on chronological age and nonverbal IQ. Verbal fluency was examined via the word association subtest of the Clinical Evaluation of Language Fundamentals (CELF-4; Semel et al., 2003). The bilingual ASD group performed unexpectedly well on the verbal fluency task, not differing from the typically-developing groups, but outperforming the monolingual ASD group with respect to number of correct words produced. These findings are in line with previous research on bilingual children with ASD (e.g., Hambly & Fombonne, 2012) and, taken together, suggest that bilingualism does not have a negative impact on the lexical-semantic skills of children with ASD.

Keywords: Executive Functions; Autism Spectrum Disorders; Bilingualism; Lexical-Semantic Abilities

Autism Spectrum Disorders (ASD) are neurodevelopmental disorders characterized by deficits in the areas of social communication and social interaction and the presence of repetitive and restricted behaviors (American Psychiatric Association, 2013). The question of how bilingualism affects language and cognitive development in children with ASD is a topical one with important consequences for education and service delivery. Some professionals suggest that bilingualism should be avoided for children with neurodevelopmental disorders (as reported by Kremer-Sadlik, 2005; Yu, 2013), yet there is no evidence to support this claim. In fact, studies investigating this question have shown no additional language delay in bilingual relative to monolingual children with ASD (Drysdale, van der Meer, & Kagohara, 2015; Hambly & Fombonne, 2012; Petersen, Marinova-Todd, & Mirenda, 2012; Ohashi et al., 2012; Reetzke, Zou, Sheng, & Katsos, 2015). However, on the one hand, difficulties in lexical access (e.g., production of fewer target words in picture-naming paradigms; Yan & Nicoladis, 2009) have been found in typically-developing bilinguals when compared to their monolingual peers (Klassert, Gagarina, & Kauschke, 2014; Yan & Nicoladis, 2009). On the other hand, in the cognitive domain, we proposed that bilingualism may act as a protective factor for specific executive functions that are often impaired in ASD, namely set-shifting and generativity (Bishop & Norbury, 2005; Ozonoff et al., 2004). If this is the case, one might expect bilingual children with ASD to perform better than monolingual children with ASD on set shifting tasks, parallel to the advantage documented in typically- developing bilingual children (e.g., Barac & Bialystok, 2012).

In this study, we investigated the performance of four groups of children on a verbal fluency task: both monolingual and bilingual children who are either developing typically or who have ASD. Verbal fluency refers to the ability to generate words according to a given criterion (e.g., belonging to a specified semantic category such as *animals* or *food*) in a limited amount of time (Troyer, Moscovitch, & Winocur, 1997). Verbal fluency tasks provide a wealth of information about both an individual's lexical and semantic abilities (Abwender, Swan, Bowerman, & Connolly, 2001), as well as his or her executive functions (Welsh, Pennington, & Groisser, 1991). Executive functions (EF) comprise skills essential for daily life such as working memory, planning, inhibition, and set-shifting (Eigsti, 2011). Although the EF profile of individuals with ASD is quite variable across studies (c.f., Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004; Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009); certain areas of difficulty in EF have consistently been reported in children with ASD, including perseverative responses in set-shifting tasks (e.g., Ozonoff et al., 2004), delayed response initiation (Hill and Bird, 2006), as well as deficits in tasks that assess planning skills (Hill, 2004). Therefore, verbal fluency is a task well-suited to provide insights into the effects of bilingualism on both the language and cognitive skills of children with ASD.

What can a verbal fluency task reveal about the cognitive and language abilities of children with ASD? Performance on a verbal fluency task relies on the use of several cognitive and linguistic abilities, which makes it of particular interest in a population that has been reported to present semantic (Tager-Flusberg, 1991) and executive functioning deficits (Kleinhans, Akshoomoff, & Delis, 2005; Ozonoff, Pennington, & Rogers, 1991). First, it requires the constant generation of new items. *Generativity* has been defined as the ability to initiate or generate ideas and responses spontaneously (Turner, 1999). Several studies in the field of ASD have found deficits in this skill for children with ASD relative to controls (Bishop & Norbury, 2005; Craig & Baron-Cohen, 1999; Turner, 1999; however see Boucher, 1988). Second, verbal fluency relies on vocabulary knowledge and the ability to retrieve words from the individual’s lexicon, along with the capacity to explore semantic networks (Henry, Crawford, & Phillips, 2004). Of interest, children with ASD have been reported to present impairments using linguistic information to retrieve words (Tager-Flusberg, 1991) and difficulties with lexical organization (Dunn, Gomes, & Sebastian, 1996). Finally, the use of executive functioning abilities such as set-shifting (e.g., switching between categories when available elements from one set have been named) and monitoring (e.g., being aware of elements already said to avoid repetition) are also involved in this task. Impairments in set-shifting ability have been found in children with ASD relative to typically-developing children as well as children with other developmental disorders (Ozonoff & Jensen, 1999). Hence, verbal fluency provides a plethora of information that can help us better identify the specific EF abilities that are challenging for children on the autism spectrum.

Multiple measures can be derived from verbal fluency tasks. One of these is the *number of correct words* generated in a specified category, which relies on lexical skills as well as response initiation and generativity skills (Robinson et al., 2009). In addition, the ability to *switch* between different sub-categories to efficiently perform the task is closely tied to the EF of set-shifting or cognitive flexibility (Troyer, 2000; Troyer et al., 1997). Responses to verbal fluency tasks often form semantic clusters (for example, when asked to name food, giving the responses of several types of fruit in succession). The *number of distinct clusters* can be taken to reflect generativity, whereas the size of such clusters (*average cluster size*) provides a window into the individual’s semantic networks (Raoux et al., 2008; Troyer et al., 1997).

Several studies have investigated the impact of bilingualism on verbal fluency in neurotypical adults with contradictory findings. Some researchers have reported disadvantages for bilinguals relative to monolinguals on number of correct words produced (e.g., Gollan, Montoya, & Werner, 2002), arguably due to between-language interference and related lexical access difficulties (Sandoval, Gollan, Ferreira, & Salmon, 2010). Other studies have not found significant differences between bilingual and monolingual adults when groups have comparable vocabulary skills (e.g., Luo, Luk, & Bialystok, 2010). Yet other studies that have compared bilingual and monolingual typically-developing (TYP) children have found decreased performance in bilinguals on semantic fluency tasks (Kormi-Nouri, Moradi, Moradi, Akbari-Zardkhaneh, & Zahedian, 2012) or, in some cases, similar performance (Friesen, Luo, Luk, & Bialystok, 2015). In addition, studies have indicated decreased performance on naming tasks in bilingual compared with monolingual children (Klassert et al., 2014; Yan & Nicoladis, 2009). Taken together, these findings suggest that bilinguals may have difficulty with lexical access in language production tasks. Yet it has been demonstrated that when bilingual and monolingual groups are matched on receptive vocabulary in the test language, they often show similar performance (Friesen et al., 2015).

In a separate literature, verbal fluency has been investigated in monolingual children with ASD relative to typically-developing peers (Begeer et al., 2014; Robinson et al., 2009). Some of these studies found similar performance in children with ASD relative to TYP comparison groups with respect to the number of correct words generated. Yet, they report different patterns of responding, namely more perseverative responses in ASD (Robinson et al., 2009) and different task strategies, with the ASD group generating longer clusters and reduced switching between clusters relative to the control group (Begeer et al., 2014). In contrast, other studies have reported significant differences between ASD and TYP groups on number of correct words produced (e.g., Geurts et al., 2004; Turner, 1999). For instance, Geurts and colleagues (2004) found children with high-functioning ASD to generate significantly fewer correct words than the control group. These mixed results warrant further investigation.

Research Hypothesis

Although there are several studies examining EF and verbal fluency in monolingual children with ASD, the impact of both bilingualism and ASD on verbal fluency has not been investigated to date. In the current study, we examined the lexical and semantic skills, as well as executive functions, revealed by performance on a verbal fluency task in four groups of 5- to 10-year-olds with and without ASD. First, following mixed findings from studies of monolinguals with ASD (e.g., Begeer et al., 2014; Geurts et al., 2004), we were neutral as to whether there would be differences between the two ASD groups and the two TYP groups with respect to *number of correct words* generated. Second, if bilingualism has a detrimental effect on lexical access, as has been reported in the TYP literature discussed above, we expected that bilingual children with ASD would perform more poorly than their monolingual ASD counterparts on the *number of correct words.* Third, regarding cluster formation, given EF difficulties and a tendency for perseveration in individuals with ASD (e.g., Eigsti, 2011), we predicted fewer *switches* in the monolingual ASD group relative to the TYP groups, potentially accompanied by larger *cluster size* (Begeer et al., 2014). Fourth, based on findings from TYP bilingual children (e.g., Bialystok & Barak, 2012), we hypothesized that if bilingualism confers an advantage for executive functioning, bilingual children with ASD may make more *switches* between sub-categories than monolinguals with ASD.

Method

Participants

The present study included 13 typically-developing (TYP) monolingual children, 13 TYP bilingual children, 13 monolingual children with ASD, and 13 bilingual children with ASD between 5 to 10 years of age. Participants were speakers of French, English, or Spanish or any two of these languages. Children were recruited in Montreal, Quebec, Canada, from schools, local autism organizations, therapy programs and a database from previous studies. Participants' demographic information is reported in Table 1 and described below.

Insert Table 1 about here

Groups were carefully group-wise matched on chronological age, $F(3, 48) = .09$, $p = .96$, given the influence of this variable on verbal fluency performance (e.g., Troyer, 2000). Children were also matched on nonverbal IQ, $F(3, 48) = .35$, $p = .79$, with participants in all groups having scores within the normal range (standard score >80) as measured by the Leiter International Performance Scale-Revised (Leiter-R; Roid & Miller, 1997). Regarding gender, there were more males than females in all groups, reflecting the higher incidence of ASD in males, $\chi^2(3) = 1.18$, $p = .76$. For monolingual and bilingual children with ASD and TYP bilinguals, an approximately equal number of children had French versus English as a dominant language. This was determined based on children's self report, parent report, and child's history of language exposure. However, matching on dominant language was not possible for the TYP monolingual group who were generally French dominant[4], given the linguistic context of Quebec where most typically-developing children attending mainstream public school have significant

[4] We refer to the monolingual children language of higher exposure as "dominant", given that these children had some minimal exposure to a second language, which in most cases was English, through school, TV, and other media.

exposure to French, even when English is their home language, resulting in a 4-group chi square value of $\chi^2(3) = 7.15$, $p = .07$. Across the four groups, the children did not differ significantly with respect to years of maternal education (15-16 years on average), $F(3, 48) = 1.47$, $p = .24$. Children with ASD had clinical diagnoses, generally done by a specialized multidisciplinary team. As a form of additional confirmation of ASD, and to rule out ASD in the TYP participants, the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) was administered to parents. The SCQ includes 40 items that provide information concerning the child's early social and communicative development, and it has been shown to be a valid tool for the screening of ASD in school-age children (Chandler et al., 2007). A score of 15 or higher on the SCQ is consistent with a diagnosis of ASD. Confirming their diagnosis, children with ASD had elevated scores compared to the TYP groups (monolingual ASD vs. monolingual TYP = $t(24) = -11.42$, $p = .00$; bilingual ASD vs. monolingual TYP = $t(22) = -10.91$, $p = .00$; monolingual ASD vs. bilingual TYP = $t(24) = -8.74$, $p = .00$; bilingual ASD vs. bilingual TYP = $t(22) = -8.47$, $p = .00$). Importantly, bilinguals and monolinguals with ASD did not differ significantly in their ASD symptomology, as per SCQ scores, $t(22) = .69$, $p = .50$. In addition, children with ASD did not have any other medical condition associated with ASD (e.g., fragile X). Finally, receptive vocabulary was significantly different across the four groups, $F(3, 48) = 10.23$, $p = .00$, with the TYP participants exhibiting higher scores relative to both groups with ASD (monolingual TYP vs. monolingual ASD = $t(24) = 3.85$, $p = .001$; monolingual TYP vs. bilingual ASD = $t(24) = 4.46$, $p = .000$; bilingual TYP vs. monolingual ASD = $t(24) = 3.19$, $p = .006$; bilingual TYP vs. bilingual ASD = $t(24) = 3.88$, $p = .001$). Critically, however, monolingual and bilingual typically-developing groups did not differ significantly on receptive vocabulary in their dominant language, $t(24) = 1.51$, $p = .14$, nor did monolingual and bilingual groups with ASD, $t(24) = .10$, $p = .93$

Procedure

Children were tested individually by trained research assistants proficient in each of the languages of interest. Bilingual participants were tested in both of their languages as part of a larger study examining the cognitive and linguistic abilities of bilingual children with ASD. Children were evaluated using multiple standardized and non-standardized measures that are reported elsewhere (Gonzalez-Barrero & Nadig, in preparation). Only verbal fluency performance and receptive vocabulary scores from the bilinguals' dominant language were considered for the present study. Participants in all groups had either French or English as a dominant language. Ethics approval was obtained from a university Institutional Review Board and both parent consent and child assent were obtained from all participants. Testing took place at a university lab or at the participants' home.

Bilingual status was based on a combination of several metrics because percent of lifetime exposure to two languages on its own was not found to accurately reflect fluent bilingualism. To be included in the bilingual group, children had to have: 1) greater than 20 percent of lifetime exposure to each of 2 languages as reported by parents, 2) the ability to complete the testing protocol in both languages, 3) 3 or 4 on a 4 point scale of language proficiency in both languages as rated by parents, and 4) mean ratings of 2 or above in both languages on a 4 point scale of language proficiency, obtained from three external raters' assessment of language use from video-recordings of the testing sessions. Monolingual participants were those who: 1) had a history of exposure to an L2 of less than 20%, 2) obtained proficiency scores of 1 or 2 in their L2 as rated by parents, or 3) could not complete the experimental tasks in both languages.

Verbal fluency was assessed using the word association subtest of the Clinical Evaluation of Language Fundamentals (CELF-4; Semel, Wiig, & Secord, 2003), or its French equivalent (Evaluation clinique des notions langagières fondamentales; Wiig, Secord, Semel, Boulianne, & Labelle, 2009); the language of testing depended on the child's dominant language. There were no Spanish dominant participants. This sub-test requires children to generate as many items as possible from a given category in 60 seconds. Categories included: animals, food, and jobs for both the English and French versions of the CELF. The last category (i.e., jobs) resulted in limited responses and was difficult to code into meaningful clusters and, therefore, is not reported here. In addition, previous studies on this topic have focused on the first two categories (e.g., Geurts et al., 2004; Roberts & Le Dorze, 1997). Thus, only data from the animals and food sub-categories were included in the present analyses.

An example was provided first to familiarize the child with the procedure (e.g. "Name as many types of clothes you can think of.") and feedback was provided. Then, each child was asked to name as many items as possible for the three categories in succession (animals, food, jobs). Standard administration and scoring guidelines from the CELF were followed. Accordingly, for each category, two examples were given to participants (e.g., *dog* and *tiger* for the animal category). If the child repeated the examples provided while performing the task they were given credit for those words.

A coding scheme for clusters was developed based on both the content of children's responses and on categories previously developed by Troyer et al., (1997) for animals and by Troster et al., (1989) for food. To be considered a *cluster*, the child had to name at least two consecutive items pertaining to the same sub-group within the category (e.g., *apple*, *banana* and *orange* could form a "*fruit*" cluster in the category of food). Three dependent variables were examined, as described below:

Number of correct words. Coding of this variable was based on the CELF guidelines. Credit was given for correct words that pertained to the specified category. When both general and more specific terms for the same item were produced, only the specific examples were scored as correct (e.g., if the child said: *dinosaur, t-rex, velociraptor, stegosaurus*, "dinosaur" was not given credit but the other three terms were). Furthermore, credit was given for only one word when children listed animals as well as their offspring (e.g., *dog* and *puppy* received one point) or both feminine and masculine names for an animal (e.g., *cock* and *hen*).

Number of switches. The number of *switches* was calculated following the procedure of Begeer et al. (2014). This included changing between clusters (e.g., from a series of jungle animals to a series of farm animals), changing between a cluster and an unclustered word (e.g., from a series of farm animals to *penguin*), or changes between two unclustered words (e.g., between *penguin* and *hamster*).

Average cluster size. The number of items in each cluster was summed and divided by the number of clusters produced by each child.

All data were coded by two raters and an intra-class correlation coefficient (ICC) was calculated for each dependent variable (number of correct words = .99, number of switches = .98 and average cluster size = .98). Results showed good agreement for all variables. Cases of disagreement were discussed and a consensus code was established.

Results

A series of two-way analyses of variance (ANOVA) were conducted to examine the effect of bilingualism (monolingual, bilingual) and diagnosis (TYP, ASD) on number of correct words, number of switches and average cluster size. A Bonferroni correction was employed to decrease the familywise error rate given multiple comparisons. As a result, the significance alpha level was set at .017. Simple effects are reported for any marginal or significant omnibus findings that were the focus of our research hypotheses.

The *number of correct words* across groups is shown in Figure 1. There was a marginally (due to the Bonferroni correction) significant main effect of diagnosis, $F(1, 48) = 6.03$, $p = .018$, partial $\eta^2 = .11$. Simple effect analyses revealed that the TYP monolingual group produced significantly more words than the monolingual group with ASD ($p = .001$). However bilingual TYP participants and bilingual participants with ASD did not differ significantly on this variable ($p = 1.0$). There was no significant main effect of bilingualism, $F(1, 48) = 1.30$, $p = .26$, partial $\eta^2 = .03$. Finally, there was a marginally significant interaction between bilingualism and diagnosis, $F(1, 48) = 6.03$, $p = .018$, partial $\eta^2 = .11$. Contrary to the prediction that bilinguals would have difficulty with lexical access compared to monolinguals, bilingual and monolingual TYP children did not differ significantly in the number of words produced on the verbal fluency task ($p = .36$). In contrast, the bilingual children with ASD produced significantly more correct words than their monolingual peers with ASD ($p = .014$).

Insert Figure 1 about here

Another set of hypotheses concerned *switches* and *average cluster size*. Contrary to our prediction for *number of switches*, a two-way ANOVA showed no significant main effect of diagnosis, $F(1, 48) = 2.86$, $p = .10$, partial $\eta^2 = .06$; no significant main effect of bilingualism,

$F(1, 48) = 1.21$, $p = .28$, partial $\eta^2 = .03$; and no significant interaction between these variables, $F(1, 48) = 3.50$, $p = .07$, partial $\eta^2 = .07$.

Similarly, no significant effects were found with respect to *average cluster size:* no main effect of diagnosis, $F(1, 48) = .63$, $p = .43$, partial $\eta^2 = .01$; no main effect of bilingualism, $F(1, 48) = .24$, $p = .63$, partial $\eta^2 = .005$, no interaction between diagnosis and bilingualism, $F(1, 48) = .95$, $p = .34$, partial $\eta^2 = .019$. Means and standard deviations for verbal fluency task measures are provided in Table 2.

Insert Table 2 about here

Discussion

The main and unexpected finding from the verbal fluency test was related to the lexical-semantic component of the task. We found a significant reduction in the generation of *correct words* related to a given semantic category in monolingual children with ASD relative to bilingual children with ASD and relative to monolingual TYP children matched on age and NVIQ. Our comparison of monolingual children with ASD with their bilingual peers with ASD and both monolingual and bilingual TYP control groups is a novel one. The current results suggest that an interaction between bilingualism and ASD allows bilinguals with ASD to produce a similar number of correct words in a verbal fluency task as their typically-developing peers, while monolinguals with ASD exhibited poorer performance. It should be noted that our sample size was modest (13 participants in each group) and this interaction was only marginally significant after conducting a Bonferroni correction; therefore, it should be interpreted with caution. Contrary to our hypotheses, we did not find any differences between any of the groups with respect to the *number of switches* or *cluster size*.

Since our bilingual and monolingual ASD groups had similar receptive vocabulary skills in their dominant language, it is striking that the bilinguals provided an increased number of correct responses on the verbal fluency task (i.e., higher number of correct words) relative to monolinguals. We speculate that this relative increase may stem from enhanced *generativity* or *response initiation* in bilingual children with ASD. Bilingualism may provide resources to children with ASD that help them *initiate* the task of naming words more easily, leading to higher scores than their monolingual peers with ASD. Notably, when studying verbal fluency in monolingual adults with ASD, Carmo and colleagues (2015) demonstrated that the key area of difficulty in adults with ASD relative to neurotypical adults was a decreased number of words produced, rather than switching or clustering measures which were found to be similar across groups. The authors attributed the lower number of correct words produced by the ASD group to deficits in *response initiation*, specifically deficiencies in word generation during the first seconds of the task. Spek, Schatorjé, Scholte, and Berckelaer-Onnes (2009) reported the same pattern of findings -- decreased word generation alongside spared switching and clustering in high functioning adults with ASD, and suggested that these deficits are related to slow processing speed. Thus, findings from monolingual adults with ASD are consistent with our finding of fewer correct words produced on verbal fluency task by monolingual children with ASD.

In our sample, we did not find a bilingual advantage or main effect of bilingualism; that is, the TYP bilingual group did not outperform the TYP monolingual group on any measure of the verbal fluency task. However, it should be taken into consideration that our monolingual groups, recruited in Montreal, Québec, had some degree of exposure to other languages (15% or less), which likely differs from the operationalization of monolingualism in other samples where there is very little or no exposure to a second language. Greater disparities in language exposure may be needed for a bilingual advantage to emerge in typically-developing children.

We had predicted, based on findings from typically-developing bilingual children and adults (Gollan et al., 2002; Klassert et al., 2014; Sandoval et al., 2010; Yan & Nicoladis, 2009), that bilinguals may have difficulty with lexical access (due to poorer lexical abilities in the test language and/or between-language interference) and, therefore, may produce fewer *correct words*. Yet, we found that bilingual and monolingual TYP children did not differ on this measure, in line with findings from Luo and colleagues (2010) with neurotypical adults, where bilingual and monolingual groups had comparable vocabulary skills. In our samples as well, bilinguals and monolinguals had similar receptive vocabulary abilities in their dominant language, which may be critical to displaying spared lexical access on verbal fluency tasks. We found that bilingual children with ASD actually produced *more correct words* relative to their monolingual peers with ASD. This is likely due to comparable vocabulary skills in both groups, along with enhanced response initiation in the bilingual ASD group as discussed above.

Our second set of predictions was related to an EF component of the verbal fluency task -- switching set to new items or clusters and cluster size. We found no difference among the four groups with respect to the *number of switches*. Contrary to our predictions, we also found no evidence for set-shifting difficulties in this task in monolingual children with ASD. Similarly, *average cluster size* did not differ reliably across groups, indicating no evidence of longer clusters in the monolingual ASD group as reported by Begeer et al., 2014. Therefore, both groups of children with ASD had similar clustering strategies to the typically developing groups.

Finally, we predicted that although monolingual children with ASD may show EF-related decrements on these measures, there may be a bilingual advantage where bilinguals perform better than monolinguals. Though this was not found with respect to the *number of switches,* which were not reduced in either ASD group relative to the typically-developing groups, we did find an advantage with respect to *number of correct words* generated by bilingual children with ASD. Importantly, verbal fluency tasks allow the possibility of using different strategies to achieve the same number of total words. For instance, one could switch frequently between small clusters (as reflected in the response pattern of our school-age participants, where monolingual typically-developing children switched on average 15 times to achieve a mean of 30 total words). An equally efficient strategy could be to switch between semantic sub-classes less often, but to build large cluster sizes within each sub-class (see Rogers and Le Dorze, 1997 for an examination of this strategy in bilingual adults and Begeer et al., 2014 for a discussion of this strategy in children with and without ASD). The "optimal" strategy to use is likely tied to an individual's developmental level, lexical ability in a given language, and real world knowledge of the category in question. Yet, unlike verbal fluency tasks, other tasks *require switching* for optimal performance. For instance, take the Dimensional Change Card Sort task (Zelazo, 2006), where the task demands involve sorting cards by one category and then another (e.g., shape and then color). We are currently analyzing performance on this task in the same sample in our lab. If there is a bilingual advantage in the ability to switch between sets (e.g., Bialystok & Martin, 2004), it is more likely to be observed in such tasks where switching is required for optimal performance.

Our study is the first to examine the impact of both bilingualism and ASD on verbal fluency ability. We focused on a narrower age range than previous studies with monolingual

ASD and TYP children (e.g., Begeer et al., 2014; Robinson et al., 2009) to have clear results about verbal fluency in school-age children, since performance on such tasks is age dependent (e.g., Troyer, 2000). Another methodological strength was the comprehensive, direct assessment of language skills combined with parent reports of language exposure and proficiency to confirm the status of the bilingual participants. However, these methodological factors resulted in a small sample size within each group. Future work should include a larger sample of bilingual children with ASD while still controlling for the typology of the languages of exposure and directly assessing both languages of bilingual participants as in the present study. Future work should extend this approach to monolingual and bilingual children with other neurodevelopmental disorders. Similarly, two forms of verbal fluency are commonly used in clinical practice and in research: semantic fluency, in which individuals generate words that belong to a specified category such as *animals* or *food* (Troyer et al., 1997), and phonemic fluency where individuals are given a letter of the alphabet and are asked to name words that begin with the specific letter (Sauzéon, Lestage, Raboutet, N'Kaoua, & Claverie, 2004). We focused on semantic fluency given that young children tend to produce more words in semantic than in phonemic fluency tasks (e.g. Koren, Kofman, & Berger, 2005) and that phonemic fluency is affected by literacy skills (Regard, Strauss, & Knapp, 1982). Future studies could explore both types of tasks to better understand phonological representations as well as semantic ones.

Conclusion

Overall, these preliminary findings suggest that monolingual children with ASD produce fewer correct words on a verbal fluency task relative to bilingual children with ASD who were matched on age and nonverbal IQ, and who had similar receptive vocabulary scores, although the finding was marginally significant after a Bonferroni correction. In fact, our bilingual sample with ASD (from a largely bilingual society) showed a similar performance to matched typically-developing bilingual and monolingual children. This finding indicates that being bilingual does not necessarily have a detrimental effect on the lexical-semantic abilities of children with ASD, contrary to conventional wisdom that bilingualism is too challenging for children with developmental disabilities. Data from our full sample on additional language and EF measures (in preparation) will allow us to better characterize the language abilities of these children and to more clearly identify if some executive function difficulties experienced by monolingual children with ASD might be reduced in children with ASD growing up in bilingual environments.

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Tables

Table 1. Demographics and other characteristics of participants

	Monolingual TYP (n=13) M (*SD*)	Bilingual TYP (n=13) M (*SD*)	Monolingual ASD (n=13) M (*SD*)	Bilingual ASD (n=13) M (*SD*)	*p* value
Age in months Range (years)	101 (*14.2*) 6;10 – 10;9	98 (*16.6*) 5;5 – 10;7	102 (*18.8*) 5;5 – 10;5	100 (*17.4*) 4;11 – 10;10	.96
NVIQ (Leiter) Range	113 (*8.5*) 100 – 125	110 (*9.9*) 101 - 135	109 (*11.4*) 91 – 131	110 (*11.6*) 91 - 123	.75
Gender	Male 11 Female 2	Male 10 Female 3	Male 12 Female 1	Male 11 Female 2	.76
Dominant language	12 French 1 English	6 French 7 English	7 French 6 English	7 French 6 English	.07
Maternal Education (years) Range	15 (2.0) 11 – 18	16 (1.8) 13 - 18	15 (2.2) 11 – 18	15 (2.7) 11 - 18	.24
SCQ^{AB} Range	1 (*1.2*) 0 – 3	4 (*3.5*) 0 - 12	22 (*6.4*) 11 – 32	20 (*5.6*) 15 - 34	.00*
PPVT^{AB} Range	129 (16.4) 99 - 160	121 (9.8) 106 - 136	99 (22.6) 78 – 140	98 (18.6) 64 - 120	.00*

Note. TYP = typically-developing children; ASD = autism spectrum disorders; M = mean; *SD* = standard deviation; NVIQ = Non-verbal IQ; PPVT = Peabody Picture Vocabulary Test; SCQ = Social Communication Questionnaire;*significant at the p<.05 level. ^{A}: significant difference between monolingual TYP relative to monolingual and bilingual ASD, ^{B}: significant difference between bilingual TYP relative to monolingual and bilingual ASD.

Table 2. Results of verbal fluency task

	Monolingual TYP (n = 13) *M* (*SD*)	Bilingual TYP (n = 13) *M* (*SD*)	Monolingual ASD (n = 13) *M* (*SD*)	Bilingual ASD (n = 13) *M* (*SD*)
Number of correct words[AB]	30 (*5.5*)	27 (*9.7*)	19 (*7.2*)	27 (*8.2*)
Number of switches	15 (*2.9*)	14 (*6.2*)	10 (*4.4*)	14 (*4.6*)
Average cluster size	2.8 (*.49*)	3.1 (*.89*)	2.9 (*.91*)	2.8 (*.51*)

Note. TYP = typically-developing children; ASD = autism spectrum disorders; M = mean; *SD* = standard deviation. [A]: significant difference between monolingual TYP and monolingual ASD, [B]: significant difference between monolingual ASD and bilingual ASD.

Figures

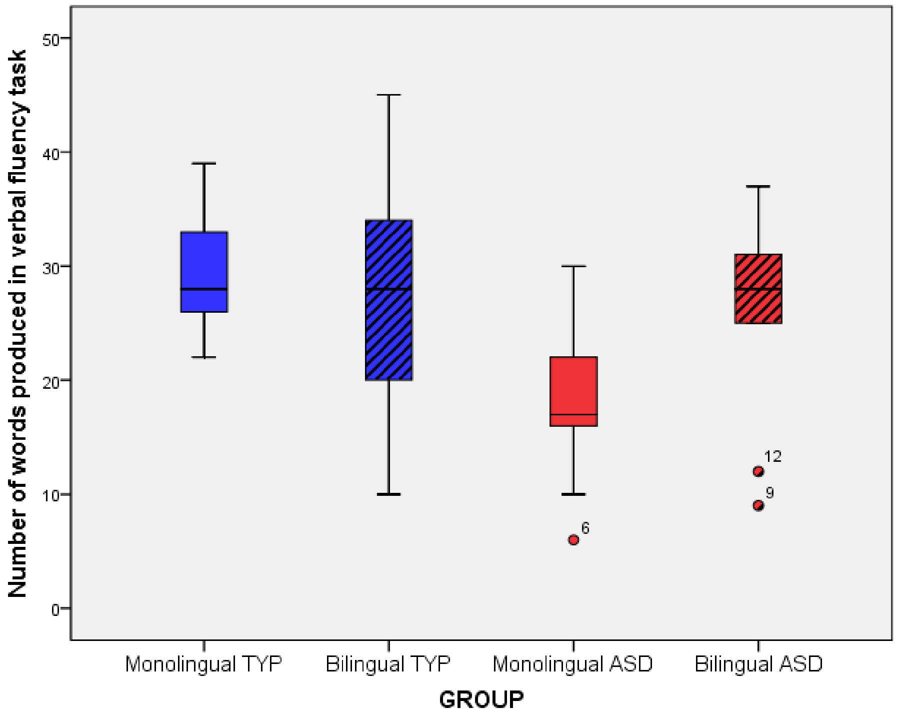

Figure 1. Boxplots showing total number of correct words by group.

Preface to Study 3

Study 2 investigated whether bilingualism confers advantages to executive functioning skills for school-age bilingual children with ASD. Results showed that bilingualism is not detrimental for the cognitive abilities of children with ASD. Instead, the bilingual group with ASD produced a significantly higher number of words on a verbal fluency task relative to the monolingual group with ASD and did not differ from the typically-developing groups. Of particular interest, no significant differences were found on the number of switches between categories in children with ASD relative to the typically-developing control groups, suggesting that similar cognitive strategies are used by children in both diagnostic groups to perform this test. However, although verbal fluency requires the ability to switch between elements of a given category to some extent, other strategies, such as the exhaustive listing of elements from the same category (e.g., farm animals) can also result in correct performance on this test. In addition, it might be possible that the lexical-semantic component of the task entails a disadvantage for the bilingual groups, given the reported difficulties with lexical access in bilinguals (Yan & Nicoladis, 2009).

Accordingly, Study 3 further examined the bilingual advantage hypothesis, this time using a non-linguistic paradigm that requires the switching of mental sets to achieve an adequate performance. Since oral language is not required to perform the Dimensional Change Card Sort Task (Zelazo, 2006), if a bilingual advantage is present, it would likely be observed in this paradigm. In addition, to provide an ecologically valid account of the effects of bilingualism on the cognitive skills of children with ASD, parents completed a questionnaire that provides information about the child’s executive functioning skills in daily life in order to explore whether a bilingual advantage can be observed in a more natural context.

7. Manuscript 3

Effects of bilingualism on the executive functioning of children with ASD: A study of set-shifting and working memory

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ABSTRACT

This study investigated the effects of bilingualism on executive functions in children with Autism Spectrum Disorders (ASD) and whether they may experience a bilingual advantage. Forty 6- to 9-year-old children participated in the study (20 children with ASD and 20 typically-developing children). Bilingual status was confirmed by a combination of direct testing and parent report. Set-shifting was measured using a computerized version of the Dimensional Change Card Sort Task (DCCS; Zelazo, 2006), along with a measure of executive functioning in daily life (BRIEF; Gioia et al., 2000). Results showed an advantage for bilingual children with ASD on the DCCS task but not for parent report of set-shifting skills. These findings build on previous research suggesting that bilingualism is not detrimental for children with ASD and in fact may provide some advantages.

Keywords: *Bilingualism, Autism Spectrum Disorders, Executive Functioning, Set-shifting*

The impact of bilingualism on cognition is an ongoing topic of debate among scholars. Multiple studies have focused on executive functions (EF) to disentangle whether the use of two or more languages confers an advantage to these cognitive skills. A number of researchers have reported enhanced performance on EF tasks for typically-developing bilingual children (e.g., Bialystok & Viswanathan, 2009; Carlson & Meltzoff, 2008), whereas others have not found significant differences between monolingual and bilingual groups (e.g., Morton & Harper, 2007; Namazi & Thordardottir, 2010). However, though EF abilities have been investigated in monolingual children with Autism Spectrum Disorders (ASD), generally showing poorer performance than that of typically-developing peers, it is unclear if bilingualism holds consequences for the EF of children with ASD. In the present study, we explore the executive functions of four groups of children: bilingual and monolingual children with ASD or typical development, with a central focus on the constructs of set-shifting and working memory, using a stringent methodological approach towards the definition of bilingualism.

Executive Functions in Autism Spectrum Disorders

Autism Spectrum Disorders (ASD) are neurodevelopmental disorders characterized by impairments in social communication and social interaction, accompanied by restricted and repetitive behaviors and interests (American Psychiatric Association, 2013). Executive functioning has been a major area of interest within the field of ASD where extensive research has been carried out during the last years (e.g., Chen et al., 2016; Griffith, Pennington, Wehner, & Rogers, 1999; Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009). Executive functions comprise an array of skills that are important for everyday functioning such as planning, inhibition, working memory, and set-shifting (Hill, 2004). The executive function of set-shifting is especially relevant to ASD given characteristic impairments in this domain (Eigsti, 2011).

Set-shifting, also called cognitive flexibility (Hill, 2004), has been defined as the ability to accurately switch back and forth between tasks given specific demands (Miyake et al., 2000). Several tests have been used to explore this construct in individuals with ASD (e.g., *Flexible Item Selection Task*, Yerys, Wolff, Moody, Pennington, & Hepburn, 2012; *Intradimensional/Extradimensional Shift Subtest*; Ozonoff et al., 2004; *Wisconsin Card Sorting Test*, Pascualvaca, Fantie, Papageorgiou, & Mirsky, 1998). Overall, it has been found that individuals with ASD tend to show poor performance on these tasks relative to typically-developing control groups. However, mixed findings are reported depending on factors such as testing modality (e.g., experimenter administration vs. computer administration), matching procedure used (matching on IQ vs. matching on language ability), and task selection (Kenworthy, Yerys, Anthony, & Wallace, 2008; Russo et al., 2007).

To study set-shifting skills in children, researchers have used the Dimensional Change Card Sort (DCCS) task (Frye, Zelazo, & Palfai, 1995; Zelazo, 2006). In a first "pre-switch" phase of the paradigm, children are asked to sort a series of simple images depicted on cards (e.g., boats and rabbits) according to one dimension (e.g., color). Afterwards, in a "post-switch" phase, they are asked to sort the same images according to another dimension (e.g., shape). To successfully perform in the post-switch phase, children need to disengage from the previously used rule and switch to a new dimension that is explicitly stated (Prior & Macwhinney, 2010). While typically-developing 5-year-olds have been shown to correctly switch from one phase to another (e.g., from sorting by color to sorting by shape), younger children tend to exhibit difficulties with the post-switch phase and continue sorting by the first dimension they were instructed to implement (Zelazo, 2006). Children who sort the images in the post-switch phase correctly, are then administered a more advanced phase in which mixed trials are presented (i.e., border version;

Zelazo, 2006). In this mixed phase, the task is to sort the images by one of the two previously used dimensions depending on a specific visual cue depicted on the card (e.g., sort by color if the image has a border and by shape if the image has no border). As reported by Zelazo (2006), different measures (e.g., reaction time) from this mixed phase have been used to assess set-shifting skills in both school-age children and adults (e.g., Bialystok and Martin, 2004; Diamond and Kirkham, 2005).

Different versions of the DCCS task (i.e., standard card version, computerized version, etc.) have been employed in the field of ASD to examine set-shifting abilities in monolingual children (e.g., Dichter et al., 2010; Faja & Dawson, 2014; Yi et al., 2012; Zelazo, Jacques, Burack, & Frye, 2002). For instance, Faja and Dawson (2014) studied the performance of 20 typically-developing (TYP) children and 23 school-age children with ASD matched on age, gender, and IQ using the standard version of the DCCS task. Results showed that accuracy on the post-switch phase for the children with ASD was comparable to that of their TYP peers. However, the TYP children outperformed their ASD peers in the advanced condition where mixed trials were administered. In another study, Yi and colleagues (2012) reported that 3- to 9-year old children with ASD, matched on verbal mental age to a TYP group, exhibited a comparable performance to their TYP counterparts during the pre-switch phase, although they exhibited deficits on the post-switch and border version of the task. Similar findings have been reported by Dichter and colleagues (2010) using a computerized version of the DCCS task with school-age children and adolescents with and without ASD. Results from Dichter et al.'s (2010) study revealed that although participants with ASD were slower and made more errors than the TYP control group, both groups were more accurate in blocks where switching was not required (e.g. pre-switch phase) than on blocks that involved constant switching between dimensions (e.g., border version).

However, the ASD and the TYP groups in Dichter and colleagues' study were not matched on nonverbal IQ, which makes the interpretation of their results problematic.

Despite multiple findings reporting impaired performance on set-shifting tasks for children with ASD (e.g., Faja & Dawson, 2014; Yi et al., 2012), it has been argued that abilities in other domains of EF, such as verbal working memory, are spared in children with ASD (Boucher, Mayes, & Bigham, 2012; Williams, Goldstein, & Minshew, 2006; however see Schuh & Eigsti, 2012 for an alternative view). This evidence comes from studies that did not find differences between high-functioning children with ASD and TYP children using tasks that tap into simple verbal working memory such as word recall (e.g., Russell, Jarrold, & Henry, 1996) and digit recall (e.g., Bennetto, Pennington, & Rogers, 1996; Williams, Goldstein, Carpenter, & Minshew, 2005).

Working memory is commonly defined as the ability to temporarily maintain and manipulate information to accomplish a specific task (Baddeley, 1992). Multiple experimental paradigms have been used to investigate working memory in ASD using visual as well as auditory stimuli (e.g., Cui, Gao, Chen, Zou, & Wang, 2010; Ozonoff & Strayer, 2001; Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008). The available evidence suggests that individuals with ASD show difficulties with complex working memory tasks that encompass high processing load (Minshew & Goldstein, 2001), and this is especially evident in the visual domain (e.g., Williams et al., 2005). In contrast, performance on simple verbal working memory tasks, such as digit recall, have been reported to be relatively intact in this population (Cui et al., 2010; Faja & Dawson, 2014; Williams et al., 2006).

While the use of EF tests to measure cognitive abilities such as set-shifting and working memory is prevalent in the field of ASD, in recent years some criticism has emerged concerning the exclusive use of these experimental tasks to study EF, given the lack of ecological validity of these instruments (Kenworthy et al., 2008). For instance, Kenworthy and colleagues (2008) have argued that to better understand the construct of EF in ASD, multiple sources of information, including reports of EF functioning in daily life, should be employed. In the present study, we follow the approach of studies that have incorporated laboratory based tasks along with parent questionnaires (e.g., Mackinlay, Charman, & Karmiloff-Smith, 2006; Winsler, Abar, Feder, Schunn, & Alarcon Rubio, 2007), providing a more comprehensive and ecologically-valid view of EF skills.

Overall, children with ASD exhibit a heterogeneous profile in their EF abilities, with consistent impairments on set shifting skills alongside relatively preserved verbal working memory, at least for simple tasks (e.g., Faja & Dawson, 2014). In addition, it has been argued that a multi-source approach should be used to investigate EF in ASD to reflect performance on laboratory tasks as well as everyday life contexts. So far, studies examining EF in ASD have only included monolingual children. Whether or not bilingualism confers an advantage in EF for children with ASD is a central topic that needs to be explored.

The Bilingual Advantage Hypothesis

Some researchers have reported that TYP bilinguals exhibit advantages in executive functioning relative to monolinguals (e.g., Bialystok & Martin, 2004; Bialystok & Viswanathan, 2009), and this has been ascribed to the effort and control bilinguals have to exert over the competing activation of their two linguistic systems (Bialystok, 2007; Green, 1998; Costa, Hernandez, & Sebastian-Galles, 2008). Advantages for bilingual children have been found in some cognitive domains such as set-shifting (e.g., Bialystok & Viswanathan, 2009), whereas it has been suggested that bilingualism does not confer an advantage in other executive functioning skills such as working memory (e.g., Bialystok, 2009; Bialystok & Feng, 2011; Engel de Abreu, 2011;

however see Delcenserie & Genesee's, 2016 findings with adults). It has been proposed that although simple working memory tasks rely on cognitive control to some degree, the use of the mechanisms involved in set-shifting paradigms (e.g., switching between sets, updating, and inhibiting a previously established rule) implies greater cognitive demands, which may explain the absence of a bilingual advantage on simple memory tasks (Engel the Abreu, 2011).

A bilingual advantage for typically-developing children has been reported in studies using the DCCS task (Bialystok, 1999; Carlson & Meltzoff, 2008; Barac & Bialystok, 2012). Barac and Bialystok (2012) administered a computerized version of the DCCS task to three different groups of bilingual children (aged 5 to 7 years) with different language pairs (Chinese-English, French-English, and Spanish-English bilinguals) and to a group of English monolingual children. Findings revealed that whereas monolingual and bilingual groups had similar reaction times (RT) for blocks in which switching was not required, for mixed blocks (e.g., border version of the DCCS task) all the bilingual groups outperformed the monolingual group by exhibiting shorter RTs.

However, the bilingual advantage hypothesis has been challenged by other researchers who have found comparable performance on EF tasks for bilinguals and monolinguals (e.g. Paap & Greenberg, 2013; Morton & Harper, 2007; Namazi & Thordardottir, 2010). These authors have ascribed the enhanced performance found in bilingual participants to factors other than bilingualism, namely, higher socio-economic status (Morton & Harper, 2007), better memory skills (Namazi & Thordardottir, 2010), and shortcomings with the statistical analyses conducted such as presence of Type I errors (Paap & Greenberg, 2013), among others. Consequently, whether bilingualism confers an advantage to EF abilities remains a topic of controversy which warrants further research.

According to the bilingual advantage, the increased demand on the underlying cognitive mechanisms required to successfully switch between languages, yields advantages on executive functioning abilities, specifically, set-shifting skills (e.g., Bialystok & Viswanathan, 2009). Interestingly, set-shifting is one of the EF domains that has been consistently reported to be impaired in individuals with ASD (e.g., Hill, 2004; Ozonoff, 1995a). In fact, set-shifting difficulties are closely related to some of the core deficits reported in ASD (i.e., presence of repetitive patterns of behaviour such as rigid thinking, difficulties with transitions, and inflexible routines; APA, 2013). Consequently, it can be hypothesized that, if bilingualism provides advantages in set-shifting skills, it is possible that proficient bilingual children with ASD may show more accurate performance on set-shifting tasks relative to monolingual children with ASD, who do not engage in constant switch between languages.

It is possible that bilingualism holds benefits for general cognitive development and executive functions for children with ASD, as has been reported for typically-developing children (e.g., Bialystok, 2001; Bialystok & Viswanathan, 2009; Carlson & Meltzoff, 2008; Poulin-Dubois et al., 2011). On the one hand, if bilingualism leads to advantages in set-shifting ability, bilingual children with ASD should outperform their monolingual peers with ASD in *set-shifting* paradigms, though both ASD groups may still exhibit impaired performance relative to TYP children. On the other hand, bilingual children with ASD may not differ from their monolingual peers with ASD in tasks that assess *verbal working memory*, as has been reported for TYP bilingual and monolingual children (e.g., Bialystok & Feng, 2011). These two hypotheses were explored in the present study, using a rigorous matching strategy and a comprehensive approach that included experimental tasks along with information concerning children's executive functions in daily life.

Method

Participants

Forty children with a chronological age range of 6 to 9 years participated in the present study (chronological age *M* = 8;0 years, *SD* = 9 months). There were 20 typically-developing children (10 monolinguals, 10 bilinguals) and 20 children with ASD (10 monolinguals, 10 bilinguals). Participants with ASD were recruited from autism organizations, schools, therapy programs, and a database from previous studies. The study was conducted in Montreal, Canada, a multicultural city where French is the official language though many people also speak English. Children were speakers of English, French, or Spanish or a combination of any of these languages. Bilingual speakers of other languages were not included in order to control for language typology and given the availability of the same standardized measures in these languages. In all groups, the majority of children were boys, given the higher prevalence of ASD in males (Baio, 2012). Information concerning maternal education was gathered as a proxy for socio-economic status and mothers from all groups had attained at least a high-school degree. Participants across groups had nonverbal IQ scores within the normal range (standard score > 80) and did not present with any acute medical conditions according to parent report. Participants were carefully group-matched on nonverbal IQ and chronological age. Nonverbal IQ was assessed using the Leiter-R (Roid & Miller, 1997), which is a completely nonverbal test appropriate for the assessment of children from different language backgrounds as well as for children with ASD.

Insert Table 1 about here

Participants with ASD had formal clinical diagnosis obtained from licensed clinicians or multidisciplinary groups from health care institutions and parents were asked to provide a copy of the diagnostic report to confirm the participant’s status. In addition, the Social Communication

Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) was used to confirm ASD symptoms. This questionnaire consists of 40 questions which provide information about the child's social functioning and early communication abilities. A score of 15 or higher on the SCQ is consisted with a diagnosis of ASD. A one-way analysis of variance (ANOVA) revealed a statistically significant difference on SCQ scores between groups, $F(3,35) = 45.50$, $p = .000$. Post-hoc tests showed that as expected, participants with ASD exhibited higher scores than TYP children ($p = .00$). However, there was no statistically significant difference between the monolingual and bilingual TYP groups ($p = .11$) or between the ASD groups ($p = .98$).

For the typically-developing (TYP) group, as for the ASD group, speakers of English, French or Spanish or a combination of these languages were recruited. In terms of inclusion criteria, we recruited children who did not have a history of language, learning or developmental difficulties, physical, visual or hearing limitations, or any family members who had been diagnosed with ASD. All children in the TYP group attended regular schools.

To assess the participants' language skills, the Peabody Picture Vocabulary Test in English (PPVT-4; Dunn & Dunn, 2007), French (Échelle de vocabulaire en images Peabody-EVIP-R, Dunn, Theriault-Whelan, & Dunn, 1993) and Spanish (Test de Vocabulario en Imagenes Peabody-TVIP; Dunn, Padilla, Lugo, & Dunn, 1986) were administered. Vocabulary measures were included given the influence of this variable on EF measures (e.g., Bialystok, Craik, & Luk, 2008; Buac, Gross, & Kaushanskaya, 2016). Furthermore, the sentence repetition subtest from the Clinical Evaluation of Language Fundamentals (CELF-4; Semel, Wiig, & Secord, 2003), along with its French (Évaluation clinique des notions langagières fondamentales; Wiig, Secord, Semel, Boulianne, & Labelle, 2009), and Spanish versions (CELF 4 Spanish Edition, Semel, Wiig, & Secord, 2006) were used to determine if participants from either diagnostic group (i.e., TYP or ASD) had language impairment. Sentence repetition is considered a useful clinical marker to identify language impairment (Conti-Ramsden, Botting, & Faragher, 2001; Thordardottir et al., 2011), and it has been used in studies examining structural language disorders in ASD (Riches, Loucas, Baird, Charman, & Simonoff, 2010). Four of 10 participants in the monolingual ASD group and 3 of 10 participants in the bilingual ASD group met criteria for language impairment as indicated by scores 1 SD below the mean on the CELF-4 recalling sentences subtest. This cut-off has been reported to provide adequate sensitivity and specificity for the identification of language impairment (Conti-Ramsden et al., 2001; Thordardottir et al., 2011). Participants with ASD and language impairment were included to reflect the heterogeneity of language abilities found in this population (Kjelgaard & Tager-Flusberg, 2001).

Conversely, all children in the TYP groups had scores within the average range (scaled score of 8 or above). Detailed information about participants' demographic characteristics is presented in Table 1.

Bilingual status. Our determination of bilingual status was based on a combination of several indices because the percent of lifetime exposure to two languages on its own was not found to accurately reflect fluent bilingualism, especially for the ASD participants[5]. To be included in the bilingual groups, children were required to have: 1) greater than 20 percent of lifetime exposure to each language (i.e., dominant and non-dominant language) according to parent report, 2) the ability to complete the testing protocol in both languages, 3) a score of 3 or 4 on a 4-point scale of language proficiency as rated by parents, and 4) mean ratings of 2 or

[5] Some participants with ASD had exposure to two languages that suggested bilingual status (e.g., History of language exposure to L2 of 30%). However, direct testing revealed that they were not able to carry on a simple conversation in their L2 nor to complete standardized tasks administered in their L2. In contrast, other children with lower percentages of exposure to an L2 *were* able to carry on a conversation and complete standardized tasks in the L2.

above on a 4-point scale of language proficiency according to the assessments of three external raters' (who were blind to bilingual status), whose ratings were based on video-recordings of the testing sessions. The 20% cut-off to determine bilingual status was based on evidence from Pearson, Fernandez, Lewedeg, and Oller (1997), who found that for children with amounts of exposure lower than 20% to each language it may be difficult to elicit utterances in each of their two languages. Concerning age of first exposure to each language, there were 7 simultaneous bilingual children in the group with ASD (i.e., children who have been exposed to both languages before three years of age; Paradis, Genesee, & Crago, 2011) and 3 early sequential bilingual children (mean age of first exposure to L2 = 4,3 years), whereas in the TYP bilingual group there were 8 simultaneous bilinguals and 2 early sequential bilinguals (mean age of first exposure to L2 = 3 years). Monolingual children were defined as those who 1) had not been exposed to a language other than English (or French for the French-L1 participants) more than 20 percent of their lifetime, 2) if exposed to an L2, had scores on that language of 1 or 2 on a 4-point scale of language proficiency completed by parents, or 3) could not complete the testing protocol in both languages, even if they did not meet criteria 1 and 2.

Procedure

Ethics approval was obtained from a university Institutional Review Board. Parental consent and children's assent were also obtained. This project was part of a larger study examining the effects of bilingualism on cognition and language development in children with ASD. Participants were tested individually by trained research assistants in a quiet room at a university lab or in the participants' homes. Testing consisted of one 2-hour session for the monolingual participants, and two sessions for the bilingual children. Since cognitive tasks where only administered in the participant's dominant language (e.g., NVIQ), the second session lasted approximately 1.5 hours. Breaks and snacks were provided as needed and participants received a small gift upon completion of each session. Sessions for the bilingual participants took place approximately 2 weeks apart, and one language (i.e., English, French, or Spanish) was used exclusively during each session. EF measures were administered during the first session of testing and only in the participant's dominant language. As part of the larger study, participants' language abilities were examined using four subtests from the CELF-4: Recalling sentences, word structure, number repetition and word associations. Data were also collected on nonword repetition and picture description tasks as well as a play-based language sample, which are presented elsewhere (Gonzalez-Barrero & Nadig, in preparation). Participants' parents filled out questionnaires concerning the child's behavior and social and communication skills (e.g., SCQ) and a questionnaire about the child's language background (e.g., child language proficiency in each language, history of language exposure, current language exposure, etc.).

Cognitive assessments.

Index of executive function in natural contexts. To obtain information concerning children's EF abilities in natural contexts, the *Behavior Rating Inventory of Executive Functioning* (BRIEF, parent form; Gioia, Isquith, Guy, & Kenworthy, 2000) was administered. The BRIEF can be used for both TYP children as well as children with neurodevelopmental disabilities, aged 5 to 18 years (Gioia et al., 2000). It has been used in previous research examining EF in children with ASD (e.g. Leung, Vogan, Powell, Anagnostou, & Taylor, 2016) and it is considered an ecologically valid measure of executive functioning (Kenworthy et al., 2008). The test consists of 86 questions that assess 8 clinical dimensions: inhibit, shift, emotional control, initiate, working memory, plan/organize, organization of materials, and monitor. These subscales can be grouped into two indices (i.e., Behavioral Regulation Index and Metacognition

Index), which, when combined, comprise an overall EF score (i.e., Global Executive Composite, GEC). T-scores are calculated and provide information about whether the child exhibits executive dysfunction in daily life (i.e., t-score > 65 is considered of clinical significance). Although data from all clinical subscales were gathered, special attention was given to the shift and working memory subscales given our specific research questions.

Set-shifting skills. Set-shifting was assessed using a computerized version of the *Dimensional Change Card Sort task* (DCCS; Zelazo, 2006) developed using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). The task was presented on a Toshiba Satellite A350 laptop with a 16-inch screen. The main reason for using a computerized task to assess set-shifting ability was to decrease the social demands that face-to-face interactions imply for children with ASD, as has been suggested in previous research that has evaluated set-shifting skills in this population (e.g., Ozonoff, 1995b; Pascualvaca et al., 1998). Furthermore, the use of a computerized version of this task allowed us to gather precise data concerning reaction times across groups in a standard form.

This experimental task was developed following the procedure of Bialystok and Martin (2004) and Barac and Bialystok (2012). A sticker with a red boat was placed on the right side of the laptop ("p" key) and a sticker with a blue rabbit was placed on the left side ("w" key). A black cover was used to hide the laptop's keyboard and only the keys of interest were kept visible. Participants sat in front of the laptop while the experimenter was next to it. The experimenter explained the rules to the participants at the beginning of each phase. Practice trials with visual (e.g., a checkmark cartoon displayed on the screen) and verbal feedback from the experimenter were administered for the pre-switch and border versions. If the child made a mistake during the practice trials, the experimenter explained the game again. No feedback was provided during the task trials. The procedure followed the administration guidelines suggested by Zelazo (2006). The stimuli appeared on the center of the screen and participants were instructed to press the key that corresponded to the condition administered (e.g., *we are going to play the color game, in the color game all the blue ones go here* -pointing to the key with the blue rabbit- *and all the red ones go here* -pointing to the key with the red boat. *Here is a blue one, where does it go?*). The image remained on the screen until the participant pressed a key to respond and there was an inter-trial interval of 2000 ms. The order of presentation during the pre-switch and post-switch phases for children in each group was counterbalanced, with half of the children presented with the color version first while the other half was administered the shape version first. Stimuli consisted of red rabbits and blue boats, thus the stimuli to be sorted never matched the stimuli on the keyboard.

For the current study, the computerized DCCS task included seven phases. In the first phase (i.e., demonstration phase), the experimenter introduced the task and explained the rules to the participant. In the second phase (i.e., practice phase), the child was asked to perform the task and received visual and oral feedback after each trial (3 trials). To continue to the pre-switch phase, the child was required to have at least 2 out of 3 correct practice trials. In the third phase (i.e., pre-switch phase, 6 trials), the experimenter reminded the child about the task, with the objective of reducing the demands on the child's working memory, and the participant was asked to sort the images based on the rule given (e.g., color). In the fourth phase (i.e., post-switch phase, 6 trials), the child was asked to change the sorting strategy and to now classify the images by another dimension (e.g., "*okay, now we are not going to play the color game anymore; now we are going to play the shape game*…" Zelazo, 2006, p. 297). In this phase, it was expected that the child would be able to disengage from the sorting strategy previously used (e.g., color) and switch to the new strategy the experimenter asked him to use (e.g., shape). As suggested by Zelazo (2006), participants were considered to pass the post-switch task if they were able to correctly sort 5 out of 6 trials in the post-switch phase.

A more complex phase was administered to participants who passed the post-switch phase. In this phase (i.e., border version, Zelazo, 2006), children were asked to sort by color if the image displayed on the screen had a border, or by shape if the image had no border, consequently referred to as “mixed condition” in the literature. A practice phase where visual and verbal feedback was provided to the participant was first presented (i.e., sixth phase, 2 trials). Afterwards, if the child obtained at least one correct response during the practice block, the participant was asked to complete the border version which included twelve trials (i.e., seventh phase). Children were considered to pass this phase if they correctly sorted at least 9 out of the 12 trials.

Accuracy (i.e., passing or failing) on the pre-switch, post-switch, and border version phases of the DCCS, along with reaction time (RT) were analyzed. RTs were measured in milliseconds. Following Diamond and Kirkham (2005), for RT analyses only correct trials were considered and trials that were less than 200 ms or 2.5 SD above the mean for each group were not included. The mean RT of the first two trials of the post-switch phase was subtracted from the mean RT of the last two trials of the pre-switch phase to obtain a RT switch cost difference score. This approach to RT analysis follows that used by Dichter and colleagues (2010) with a group of monolingual children with ASD. In addition, mean RT for the border version (i.e., mixed condition) was examined to investigate if the bilingual advantage reported by Barac and Bialystok (2012) for TYP bilingual children could be replicated in the present study.

Verbal working memory. To assess short-term and working memory, the number repetition subtest of the Clinical Evaluation of Language Fundamentals (CELF-4; Semel, Wiig, & Secord, 2003), along with its French (Évaluation clinique des notions langagières fondamentales; Wiig, Secord, Semel, Boulianne, & Labelle, 2009), or Spanish versions (CELF 4 Spanish Edition, Semel, Wiig, & Secord, 2006) were used. In this task there were 8 number series of increasing complexity (ranging from two to nine digits), that the child was asked to repeat immediately after the examiner (i.e. number repetition forward). In addition, there were 7 items (ranging from two to eight digits) in which the child had to repeat the digits uttered by the experimenter backwards (i.e. number repetition backwards). For both, number repetition forward and backwards, each digit sequence had two items. Administration and scoring followed the guidelines provided in the CELF-4 manual. Number repetition forward is considered a measure of short-term memory, whereas number repetition backwards is a more complex measure that taps into both short-term and working memory (e.g., Eigsti, 2011; Engel de Abreu, 2011). Although we were primarily interested in number repetition backwards, which assesses working memory, both subtests (number repetition forward and backwards) were administered to provide participants with the regular administration of the task that involves a gradual increase of complexity. Only the scaled score for number repetition backwards was considered for data analysis.

Results

To examine the impact of bilingualism on EF, two-way (2 Diagnostic group x 2 Language status group) analyses of variance (ANOVA) were conducted on continuous variables (i.e., Shifting and working memory scores from the BRIEF, DCCS RTs, and working memory scaled score from the CELF). For categorical variables (i.e., DCCS task accuracy/passing), Fisher's exact tests were performed. In addition, correlation analyses were conducted to explore the relationship between scores based on parent report and direct testing of EF measures. Bonferroni corrections were used for measures where multiple tests were performed (e.g., DCCS and BRIEF) to avoid Type I errors. Therefore, the applicable alpha level for significance is presented for each measure. Means and standard deviations on all EF measures are provided in Table 2.

Insert Table 2 about here

Set-shifting (BRIEF).

First, t-scores from the shift subscale (BRIEF; Gioia et al., 2000) were analyzed to assess the validity of the responses provided by parents. For this purpose, we used the inconsistency scale from the BRIEF. This scale compares similar items from the BRIEF to which parents are expected to provide consistent answers. A score is derived from this scale indicating whether the questionnaire can be considered acceptable, questionable, or inconsistent. Results showed that for the majority of children, scores were consistent. However, two participants in the monolingual ASD group showed questionable scores and were therefore excluded from analyses involving the BRIEF. Two statistical analyses were conducted using the BRIEF scores (i.e., shift subscale and working memory subscale); therefore the alpha level for significance was set at p <.025.

A 2 (Diagnostic group) x 2 (Language: bilingual, monolingual) ANOVA on shift scores revealed only a significant main effect of diagnostic group, $F(1, 34) = 43.12$, $p = .000$, partial $\eta^2 = .56$, where TYP participants obtained lower scores than participants with ASD. As previously described, higher scores on the BRIEF (i.e., t-scores > 65) reflect a greater degree of difficulty in

EF (Gioia et al., 2000). Conversely, there was no significant main effect of language, $F(1, 34) = .08$, $p = .78$, partial $\eta^2 = .00$, nor was the interaction between diagnostic group and language significant, $F(1, 34) = .88$, $p = .36$, partial $\eta^2 = .03$.

Set-Shifting (DCCS task accuracy/passing).

In contrast to results from the BRIEF, performance on the DCCS task during the pre-switch and post-switch phases was highly accurate across groups. Consequently, following Diamond and Kirkham (2005), statistical analyses were not conducted on accuracy data in these phases (available in Table 2) given the minimal variation observed. The percentage of participants passing the pre-switch, post-switch and border versions of the DCCS using the criteria of Zelazo (2006) are presented in Figure 1. Results showed that children in all groups passed the pre-switch phase, and the majority of participants in each group passed the post-switch phase (passing criteria: 5 correct trials out of 6), so no further analyses were conducted on these phases. However, for the border version (passing criteria: 9 correct trials out of 12), Fisher's exact test showed a significant difference across the four groups ($p = .024$). To further examine this difference, pairwise Fisher's exact tests were performed. Results revealed that, in line with our hypothesis, bilingual participants with ASD exhibited better performance relative to their monolingual ASD counterparts ($p = .026$). In fact, the bilingual ASD group, also outperformed the TYP bilingual group on the border version of the DCCS task ($p = .009$). On the other hand, the TYP groups did not differ significantly by language status ($p = .347$). The monolingual TYP and monolingual ASD groups performed similarly ($p = .619$).

Insert Figure 1 about here

Set-shifting (DCCS RTs).

The significance level for analyses concerning RTs was set at $p < .025$, given the two statistical analyses conducted (one on switch cost between pre- and post- phases and the other on mean RT of the border phase). A 2-way ANOVA was performed on RT switch cost (i.e., mean RT of first two trials from post-switch phase subtracted from mean RT of last two trials from pre-switch phase). The interaction between diagnostic group and language group did not reach significance ($F(1, 33) = .46$, $p = .50$, partial $\eta^2 = .01$). Similarly, the main effect of diagnostic group was not significant, $F(1, 33) = 2.97$, $p = .09$, partial $\eta^2 = .08$, although a trend was observed in which the TYP groups were faster than the groups with ASD. Finally, the main effect of language status, $F(1, 33) = .46$, $p = .50$, partial $\eta^2 = .01$, was not statistically significant, contrary to previous studies with TYP children (Barac & Bialystok, 2012). RT for switch cost for each group are presented in Figure 2.

Insert Figure 2 about here

For the border version, mean RTs were analyzed using a 2-way ANOVA. The interaction between diagnostic group and language was not statistically significant, $F(1, 28) = .02$, $p = .89$, partial $\eta^2 = .00$. The main effect of diagnostic group was not significant, $F(1, 28) = 2.82$, $p = .10$, partial $\eta^2 = .09$, and the main effect of language revealed that, contrary to previous findings, the monolingual TYP and ASD groups were faster than the bilingual TYP and ASD participants in the border version of the DCCS task, $F(1, 28) = 6.32$, $p = .018$, partial $\eta^2 = .18$. (see Figure 3).

Insert Figure 3 about here

Verbal working memory (BRIEF).

A 2-way ANOVA conducted to examine working memory in everyday life, as assessed by parent report using the t-scores from the corresponding BRIEF subscale, revealed a significant main effect only for diagnostic group, $F(1, 34) = 12.63$, $p = .00$, partial $\eta^2 = .27$, with the ASD group having higher scores, reflecting poorer performance, relative to the TYP groups. The main effect of language, $F(1, 34) = .005$, $p = .95$, partial $\eta^2 = .00$, and the interaction, $F(1, 34) = 1.39$, $p = .25$, partial $\eta^2 = .04$, were not statistically significant.

Verbal working memory (CELF-4).

Participants' performance on the experimental verbal working memory measure (i.e., scaled score from the number repetition backwards subtest from the CELF-4) was examined. In line with our predictions, results revealed that there was no significant main effect for diagnostic group, $F(1, 36) = .40$, $p = .53$, partial $\eta^2 = .01$, or for language, $F(1, 36) = .96$, $p = .34$, partial $\eta^2 = .03$, nor a significant interaction between diagnostic group and language for this variable, $F(1, 36) = .003$, $p = .95$, eta squared = .00.

Correlations between BRIEF scores and experimental tasks.

Finally, Kendall's tau-b correlations were run to examine the relationship between parent report of EF behaviors in daily life as measured by the BRIEF scores and experimental tasks of EF. For the set-shifting variables (i.e., BRIEF shifting subscale and DCCS switch cost) there was not a statistically significant correlation, $\tau_b = .054$, $p = .645$. Similarly, results from the working memory measures (i.e., BRIEF working memory subscale and number repetition subtest from the CELF-4) revealed no significant correlation, $\tau_b = -.116$, $p = .334$.

Discussion

The current study provides new insights into the cognitive abilities of children with ASD growing up in a bilingual context. Overall, results showed no significant differences between monolingual and bilingual children with ASD on measures of set-shifting and working memory in everyday life as reported by parents. However, in an experimental paradigm (i.e., DDCS task) bilingual children with ASD exhibited superior performance relative to their monolingual peers with ASD, while no significant differences were found on a working memory task. These results are discussed in depth in the following paragraphs.

Set-Shifting in Daily Life

Findings from this study suggest a number of effects of bilingualism on the cognitive skills of this population. First, regardless of language status, and as anticipated, children with ASD exhibited set-shifting difficulties in everyday life relative to their same-age TYP peers, as shown by results from the BRIEF. Both groups with ASD scored within the dysfunction range on this subscale, whereas the TYP participants' scores were in the average (typical) range. These findings suggest that monolingual and bilingual children with ASD show deficits in set-shifting skills in everyday life; this probably reflects the fact that many of the contextualized behaviors assessed by the BRIEF depict complex situations that do not involve exclusively set-shifting but also other EF components which are challenging for children with ASD. Importantly, bilingualism did not have a differentially negative impact on the cognitive skills of the children with ASD since their scores were not significantly different from those of the monolingual children with ASD. Thus, contrary to our first hypothesis of enhanced set-shifting skills for the bilingual groups, results did not show an advantage for bilinguals in either the TYP or ASD subgroups when examining EF skills in daily life, nor did they reveal enhanced difficulties among bilingual children with ASD in comparison to their monolingual peers with ASD.

Executive Functioning in Experimental Paradigms

Contrary to expectations, a direct measure of set-shifting ability, in which social demands were reduced (i.e., computerized DCCS task), did not show the characteristic impairment in set-shifting reported by previous studies with monolingual children with ASD (e.g., Faja & Dawson, 2014; Yi et al., 2012). Also, surprisingly, the bilingual ASD group performed extremely well in passing one phase of this task (i.e., border version of the DCCS task), outperforming monolingual children with ASD as well as the TYP bilingual group. We predicted better performance for the bilingual ASD group relative to their monolingual ASD peers, which was observed, yet the TYP bilingual group did not demonstrate an advantage. On the other hand, we expected the TYP participants to outperform both groups of participants with ASD. Yet, results revealed a significant difference in the opposite direction, with the bilingual ASD group performing significantly better relative to the bilingual TYP group. Why might this advantage be observable only in the bilingual children with ASD and not in the bilingual TYP group? One possibility is related to task demands and group strengths. Children with ASD have been shown to exhibit better performance in cognitive tasks that employ a computerized administration (Ozonoff, 1995b; Pascualvaca et al., 1998), as was the case of the experimental task used in this study. On the other hand, a computer-administered task has not always been shown to confer advantages to TYP children on set-shifting paradigms (Pascualvaca et al., 1998). That is, TYP children might perform better on tasks that involve social interaction (e.g., standard version of the DCCS). In fact, during the administration of the computerized DCCS task, it was observed that some TYP children (5 monolinguals, 2 bilinguals) looked at the experimenter waiting for her verbal feedback on their performance during the border version, while, although present, this behavior was less prominent among the ASD groups (1 monolingual, 2 bilinguals). In addition, children in both ASD groups seemed more motivated and engaged with the computerized task than did their TYP peers. In fact, some of them verbally expressed high levels of enjoyment during the task and even wanted to continue "*playing the computer game*".

A second possible reason for the enhanced performance of the bilingual ASD group is the degree of explicitness of the task. It has been reported that task explicitness influences the performance of individuals with ASD in set-shifting tests (Van Eylen et al., 2011), with better accuracy rates for ASD groups in tasks that provide clear and explicit rules (e.g., DCCS task) relative to tests in which rules are implicit and need to be inferred (e.g., *Wisconsin Card Sorting Task*, *WCST*). Since sorting criteria for the DCCS task were explicitly stated, this may explain the relatively high performance of the ASD groups in the pre-switch and post-switch phases. However, in the mixed phase (i.e., border version), it was the bilingual ASD group who performed significantly better than the monolingual ASD group, whereas no difference was found between the TYP groups. Thus, a bilingual advantage was found but only for the ASD group in the more advanced phase of the DCCS task. These findings are in line with previous research that have suggested spared skills in experimental tasks examining set-shifting in children and adults with ASD (Edgin & Pennington, 2005; Hill & Bird, 2006), and suggest that bilingualism confers an advantage for proficient bilingual children with ASD on a computerized measure of set-shifting.

A third contributor to the lack of a bilingual advantage for the TYP group could be related to the language or cultural background of the children in the TYP monolingual group. The dominant language[6] of the TYP monolingual children was French, whereas the TYP

[6] We refer to dominant language, even for monolingual children, given that some of these children have minimal exposure to a second language (which in most cases was English) through television, music, video games, or formal school classes.

bilingual children included children with both French (n = 6) and English (n = 4) as dominant languages. Language typology has been found to yield different results in metalinguistic tasks for bilinguals (e.g., enhanced performance for Spanish-English bilinguals but not for Chinese-English bilinguals; Barac & Bialystok, 2012); however, these differences have not previously been observed in the cognitive domain (Barac & Bialystok, 2012). In the current study, we considered language background and included a similar number of speakers of the languages of interest in three of the groups (i.e., TYP bilinguals, Monolingual ASD, and Bilingual ASD). However, it was not possible to find TYP English-speaking monolingual children who did not have a significant amount of exposure to French, given the demographics of Montreal and the fact that children in regular English languages schools receive French instruction. Consequently, only monolingual French speaking children were included in the monolingual TYP group and this could have influenced the findings (i.e., no difference in passing the border phase between monolingual and bilingual TYP children). Further research is needed to understand the role that language or cultural background may play on EF in both TYP children and children with ASD.

Although novel and revealing, the previously discussed findings concerning the superior performance of bilingual children with ASD on the border version of the DCCS task need to be interpreted with caution given our small sample size. In addition, replication with a larger well-characterized sample (i.e., confirmation of bilingual status, inclusion of NVIQ measures, description of language abilities, etc.) like our own is needed to have a more comprehensive understanding of the EF abilities of bilingual and monolingual children with ASD.

In research on typically-developing children and adults, the bilingual advantage in cognitive flexibility has been mostly reported when RTs are analyzed (e.g., Prior & MacWhinney, 2009; but see Morton & Harper, 2007). The general finding is that bilinguals exhibit smaller switching costs relative to monolinguals during non-linguistic set-shifting paradigms (Prior & MacWhinney, 2009). Yet the RT analyses in the present study revealed that the ASD groups, specifically the bilingual ASD participants, tended to be slower in the pre-switch and post-switch phases of the DCCS task in comparison to the TYP groups. These findings are in line with previous studies reporting overall slower performance for monolingual children with ASD relative to TYP controls on computerized tasks examining set-shifting (e.g., Dichter et al., 2010). Nonetheless, our findings demonstrate that children with ASD can successfully perform simple set-shifting tasks but at a slower rate than TYP children. Furthermore, all groups showed longer RTs in the mixed condition (i.e., border version) relative to the non-switch conditions (i.e., pre- and post-switch phases), suggesting that constantly switching between dimensions is taxing not only for children with ASD but also for TYP children. The switch cost analyses did not reveal significant differences between groups. Similar results were found in a study that included a group of monolingual children with ASD and monolingual TYP controls who were administered a simple card sort task (Yerys et al., 2015). For the border version, the present results did not show faster RT for the bilingual groups; therefore, the previously reported bilingual advantage on mixed blocks for TYP children (Barac & Bialystok, 2012) was not found. Instead, the significant effect of language revealed that both monolingual groups (i.e., TYP and ASD) exhibited faster RTs for this phase of the DCCS task relative to their bilingual peers. However, it has to be considered that a small number of blocks and trials were administered in the present study, given that our main interest was to examine the performance of bilingual and monolingual children with ASD on a computerized version of the standard DCCS task. Future studies examining RTs on set-shifting should administer experimental tasks with multiple trials that allow the examination of relevant measures such as switching cost, which has been shown to be enhanced in TYP bilinguals (e.g., Bialystok & Viswanathan, 2009; Prior & Macwhinney, 2009).

Paradox between Accuracy and Reaction Time in the DCCS task

An interesting finding from this study is the paradox of more accurate performance on the border version of the DCCS task for the bilingual children with ASD at the expenses of slower RTs. Specifically, the bilingual ASD group exhibited high accuracy scores in this mixed phase, but it took somewhat longer to complete the task. First, these findings suggest that impaired performance in set-shifting is likely to be observed for both monolingual and bilingual children with ASD in experimental paradigms that are timed, have fast changing conditions, and for which rules are not explicitly stated. However, when these factors are considered, children with ASD are able to switch to a new condition (e.g., from the pre-switch to the post-switch phase of the DCCS task), but only bilingual children with ASD seem to exhibit accurate performance in the mixed phase of these paradigms (i.e., border version).

Working Memory in Daily Life and Experimental Task

Results from our working memory analysis revealed that children with ASD exhibited difficulties in this domain in their everyday life, as indicated by a tendency towards high scores on the BRIEF. However, scores from this questionnaire (i.e., BRIEF) suggest that the ASD groups were not as impaired in this domain as they were on set-shifting abilities. While scores from both groups with ASD for set-shifting skills were above the threshold for executive dysfunction, their scores did not reach clinical significance on the working memory subscale. These findings support previous research on ASD suggesting heterogeneous profiles in EF for children with ASD (Happé, Booth, Charlton, & Hughes, 2006; however see Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009). Furthermore, as predicted, bilingualism did not enhance the verbal working memory abilities of children in the TYP or ASD groups as measured by direct testing of this skill. Specifically, scores on the number repetition backwards subtest of the CELF-4 showed comparable performance between groups. These results are in line with previous studies that have not found significant differences on simple working memory tasks between monolingual children with ASD and TYP children (Faja & Dawson, 2014). Thus, verbal working memory seems to be an area of relative strength for children with ASD as observed in results from the BRIEF and our experimental task.

Relationship between Experimental Tasks and Skills in Daily Life

The dissociation between intact performance on the experimental EF tasks but impairments in EF skills in everyday life, as shown by the lack of significant correlations between these measures, has been discussed by other researchers in the field of ASD (Geurts, Corbett, & Solomon, 2009; Kenworthy, et al., 2008; Nadig, Seth, & Sasson, 2015). These researchers have advocated for more comprehensive and ecologically valid approaches in the study of cognitive flexibility in ASD. In the present study, we found relatively preserved set-shifting skills for ASD participants on an experimental task with reduced social interaction and, in fact, an advantage on accuracy for the bilingual ASD group in the mixed condition. However, deficits in behaviors involving set-shifting skills were reported by participants' parents. These contradictory results might be related to the specific skills being assessed in these different contexts. Although the DCCS taps into cognitive skills other than set-shifting abilities (e.g., attention), cognitive flexibility in day-to-day life definitely involves an array of EF abilities and social demands, and this may explain the different results obtained in these measures. Instead of approaching these differences as a problem, this should be taken as an opportunity to better understand the cognitive mechanisms that underlie EF in ASD in different contexts and the possibility of using tasks in which children with ASD present spared performance to improve EF abilities in everyday life. For instance, if children with ASD are able to switch between sets using a computer-based task although they take longer to do it, this could be considered a strategy to assist them in the completion of school or home activities that involve this EF skill. In addition, these results suggest that it might be worthwhile to examine intervention strategies that gradually shift from computer-based cognitive flexibility paradigms to the integration of EF skills in daily-life.

Contributions of the Current Study and Future Directions

To our knowledge, the present study is the first to examine the effects of bilingualism on the set-shifting and working memory skills of proficient bilingual children with ASD. To ascertain children's bilingual status, this study considered measures of language exposure as well as direct testing in both languages of the bilingual participants and also included ratings by external judges. Another strength of this study was that participants were from the same city and for the most part shared similar cultural and educational backgrounds, and both experimental and daily-life measures of set-shifting and working memory were gathered.

Investigating the effects of bilingualism on cognition is not an easy endeavor given the wide variation in definitions of who is consider bilingual and in the experimental tasks used, among others (Baum & Titone, 2014). Furthermore, the recruitment of special populations, as is the case of bilingual children with ASD, is a challenging task that can be addressed by the collaboration between researchers in multiple sites. In addition to engaging larger samples of bilingual children with ASD, future studies could include neuroimaging techniques to better elucidate the mechanisms used by children with ASD who are growing up in a bilingual context to perform EF tasks and whether this differs relative to their monolingual ASD peers.

Conclusions

Overall, the present findings go beyond previous results that have shown that bilingualism is not detrimental for the language development of children with ASD (e.g. Hambly & Fombonne, 2012) and, specifically suggest that bilingualism does not negatively affect the cognitive abilities of these children. To the contrary, bilingualism might actually enhance the performance of children with ASD on experimental tasks that reduced the burden of social interaction and build up in skills such as visual ability, as is the case of the computerized version of the DCCS task.

The switch cost advantage reported by others for typically-developing bilinguals (Barac & Bialystok, 2012) was not found in the present study. However, it has to be considered that in the present study, the number of participants in each group was small and it is possible that an advantage might be observed in a larger sample. On the other hand, the effect on executive functioning of bilingualism was *selective* insofar as there was an advantage for set-shifting but not for working memory. The selective influence of bilingualism on some cognitive skills of TYP individuals has been previously discussed (Bialystok, 2009). The present results corroborate this pattern in a population with a neurodevelopmental condition, revealing that some skills can be enhanced by the constant manipulation of two languages (i.e., set-shifting accuracy in a mixed condition), whereas no effects are observed in other domains (i.e., simple verbal working memory).

Further research on this topic is warranted given the increased number of families with children with ASD in which the use of two or more languages is a common and valued practice (Kay-Raining Bird, Trudeau, Sutton, 2016). Specifically, more empirical evidence is needed to inform the decisions of parents of children with ASD who would like their children to grow up in a bilingual context and for clinicians to advise and support parents about this important decision.

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Tables

Table 1

Participants Characteristics and Demographic Information

	Monolingual TYP *(n = 10)* *M (SD)*	Bilingual TYP *(n = 10)* *M (SD)*	Monolingual ASD *(n = 10)* *M (SD)*	Bilingual ASD *(n = 10)* *M (SD)*	*P*
Age in months	93 *(7.56)*	95 *(8.93)*	100 *(11.94)*	97 *(7.23)*	.36
Range (Years)	*6;10 – 8;9*	*6;11 – 8;11*	*6;1 – 9;3*	*7;3 - 9;2*	
NVIQ	111 *(7.44)*	108 *(7.61)*	109 *(11.64)*	111 *(9.63)*	.86
Receptive Vocabulary	136 *(13.37)*	118 *(6.20)*	111 *(22.89)*	98 *(15.75)*	.00
Sentence Repetition	13 *(2.10)*	10 *(1.17)*	9 *(4.24)*	8 *(4.14)*	.01
Maternal Education (Years)	15 *(1.73)*	16 *(1.49)*	16 *(2.06)*	15 *(3.03)*	.29
Dominant Language	10 French	6 French 4 English	6 French 4 English	5 French 5 English	.08
Gender	7 males	7 Males	10 Males	8 Males	.35
SCQ	2 *(1.27)*	5 *(3.44)*	18 *(6.67)*	19 *(3.63)*	.00

Note. TYP = typically-developing; ASD = autism spectrum disorders; NVIQ = nonverbal IQ composite score from the Leiter-R; Receptive vocabulary = standard score from the Peabody

Picture Vocabulary-4 or its French and Spanish versions; SCQ = Social Communication Questionnaire total score.

Table 2

Results from Executive Function Measures by Groups

	Monolingual TYP (*n* = 10) *M* (*SD*)	Bilingual TYP (*n* = 10) *M* (*SD*)	Monolingual ASD (*n* = 10) *M* (*SD*)	Bilingual ASD (*n* = 10) *M* (*SD*)
BRIEF				
Set-Shifting [a]	45 (*5.60*)	49 (*9.07*)	69 (*11.41*)	67 (*11.50*)
Working Memory [a]	51 (*10.23*)	46 (*9.78*)	59 (*12.52*)	63 (*10.96*)
DCCS Task Accuracy				
Pre-Switch (6 trials)	5.8 (*.42*)	5.9 (*.32*)	5.7 (*.48*)	6.0 (*.00*)
Post-Switch (6 trials)	5.5 (*.85*)	5.7 (*.68*)	4.2 (*2.3*)	4.9 (*2.13*)
Border version [b d] (12 trials)	9.5 (*2.39*)	7.0 (*2.24*)	9.0 (*2.24*)	10.88 (*1.13*)
DCCS Task RT				
Pre-Switch	1326 (*284*)	1558 (*567*)	1431 (*278*)	1972 (*570*)
Post-Switch	1503 (*299*)	1451 (*303*)	1732 (*298*)	1918 (*267*)
Border version	2909 (*835*)	3786 (*1664*)	2233 (*502*)	3217 (*522*)
DCCS Switch Cost	887 (*516*)	751 (*640*)	1156 (*1076*)	1368 (*854*)
Working memory CELF-4	12 (*2.35*)	11 (*2.11*)	11 (*3.06*)	10 (*3.31*)

Note. * N varies depending on test. TYP = typically-developing children; ASD = autism spectrum disorders; BRIEF = Behavior Rating Inventory of Executive Functioning; DCCS = Dimensional Change Card Sort task. [a]: significant difference between TYP group and ASD group, [b]: significant difference between monolingual TYP and bilingual TYP, [c]: significant difference between monolingual ASD and bilingual ASD, [d]: significant difference between bilingual TYP and bilingual ASD.

Figures

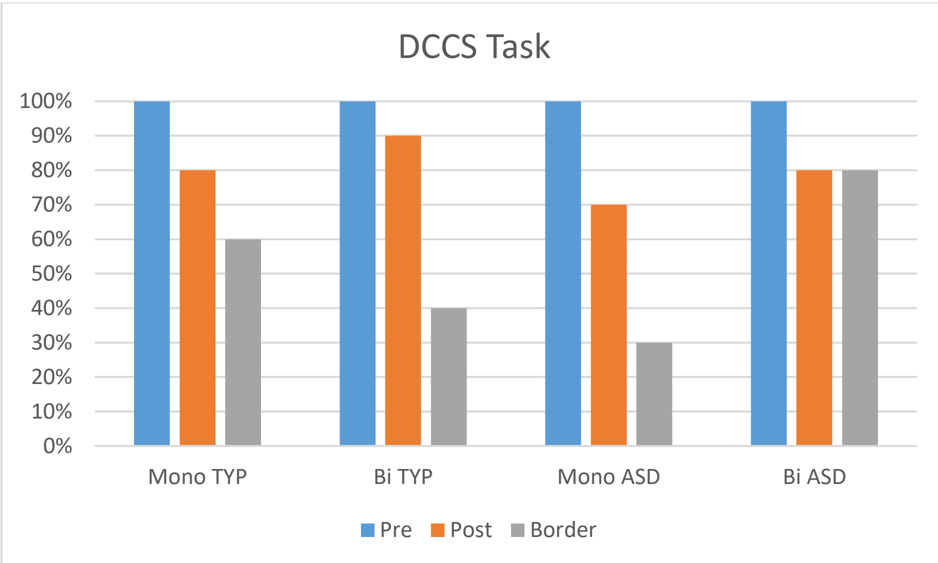

Figure 1. Percentage of participants passing each phase of the Dimensional Change Card Sort task by Group.

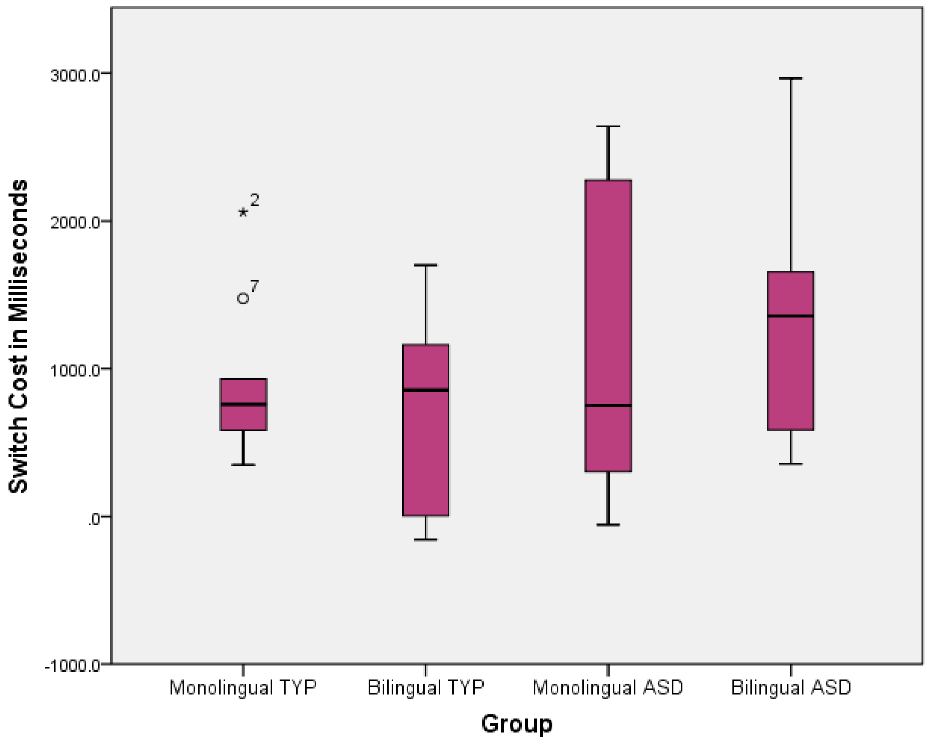

Figure 2. Boxplot showing switch cost (slowing) between the pre-switch to post-switch phases of the Dimensional Change Card Sort Task by Group. Boxplots display the distribution of data including the minimum, first quartile, median (bar through the box), third quartile, and maximum values.

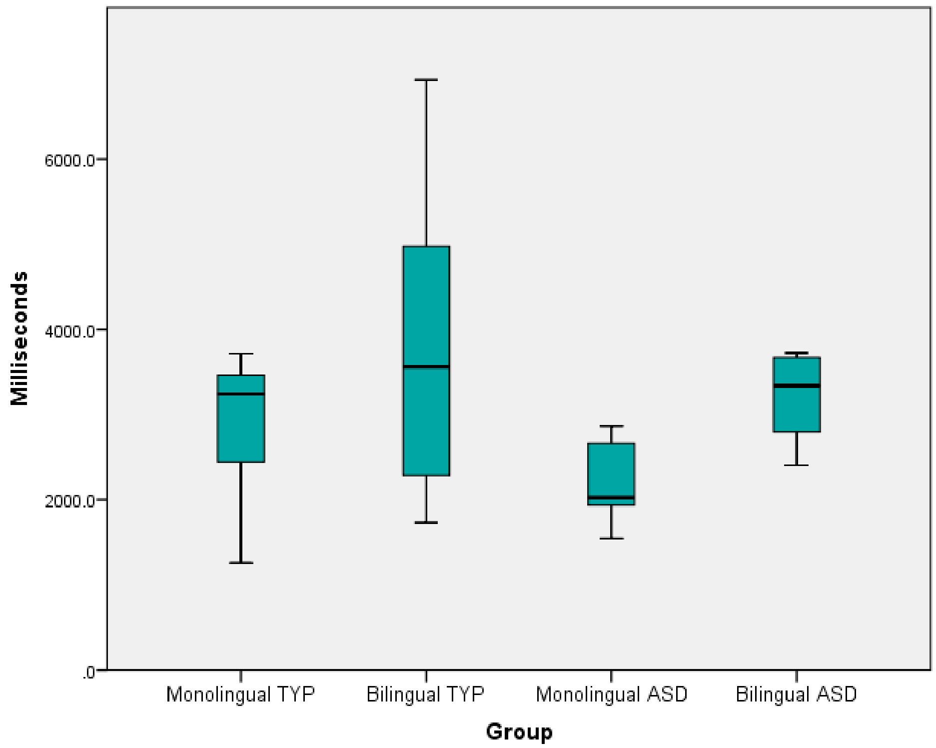

Figure 3. Boxplots of reaction time for Border Version of the Dimensional Change Card Sort Task by Group. Boxplots display the distribution of data including the minimum, first quartile, median (bar through the box), third quartile, and maximum values.

8. General Discussion and Conclusions

The goal of the present dissertation was to investigate the effects of bilingualism on the linguistic and cognitive abilities of children with ASD. More specifically, Study 1 examined whether proficient bilingualism is possible for children with Autism Spectrum Disorders (ASD) and, as well, the predictive role of current amount of language exposure on vocabulary and morphology measures. The results of Study 1 showed that children with ASD can indeed become bilingually proficient, and that this is related to (though not determined by) the amount of exposure they have to each language, as for typically-developing (TYP) children. Having established that proficient bilingualism is possible for children with ASD, we could then extend the “bilingual advantage” hypothesis (Bialystok et al., 2009) to this population. Specifically, we tested whether the effort bilinguals exert over the competing activation of their two linguistic systems (Bialystok, 2007; Green, 1998) yields benefits in set-shifting skills. Study 2 explored this hypothesis using a lexical-semantic task that also relies on executive functioning, namely, verbal fluency. Finally, Study 3 further examined if a bilingual advantage is observed in an experimental set-shifting paradigm that does not require oral language, and whether benefits might be observed in children’s daily behaviours.

Using a detailed methodological approach, the studies that comprise this dissertation provide novel evidence concerning the effects of bilingualism on language and executive functioning in children with ASD. The examination of these areas is an important contribution to the field of ASD, considering that prior research has primarily focused on *bilingually exposed* children’s abilities at early ages, while the present studies examined *bilingual proficiency* in school-age children with ASD. In the current project, the determination of participants’ bilingual status was based on multiple complementary sources: direct testing, a thorough parental questionnaire of children's language exposure history, and proficiency scores from blind judges. In contrast, the majority of prior studies relied primarily on parent report to determine bilingual status, and included children from numerous language backgrounds in the bilingual group. In the present studies, we also closely matched our groups on several variables that are important in the study of language and executive function in TYP children as well as children with ASD, specifically, NVIQ, age, SES, dominant language, gender, and SCQ scores. We also recruited children from specific language backgrounds (i.e., speakers of English, French or Spanish), given that we could assess these languages with similar standardized tests and that language typology has been linked to effects in some languages more than others (e.g., enhanced metalinguistic skills in Spanish-English bilinguals but not in Chinese-English bilinguals, Barac & Bialystok, 2012).

Beyond the methodological strengths concerning participant characterization and matching, to our knowledge, this is the first study that has investigated the relationship between bilingualism and executive functioning in children with ASD, using both experimental paradigms and information concerning children's everyday behaviours via parent report. This is an important contribution of this dissertation considering that researchers have argued the need to connect findings gathered under experimental conditions to behaviour in daily life (Geurts et al., 2009). In addition, we examined set-shifting ability using tasks that involve different modalities (i.e., one requiring oral language and one that does not involve a verbal response) to better understand how task requirements affected performance in both children with ASD and TYP children. The main findings from each study, as well as their implications, limitations and venues for future research are next discussed.

Summary of Findings

One of the most significant findings to emerge from this dissertation is that proficient bilingualism is possible for some children with ASD. Findings from Study 1 revealed that although bilingual children with ASD tended to perform below their monolingual peers with ASD, mirroring findings from studies of TYP children (e.g., Bialystok et al., 2010), our high-functioning subgroup of children with ASD exhibited scores within the average range on the PPVT. In addition, scores from the CELF-4 word structure subtest showed that the bilingual group with ASD was not significantly different from the monolingual group with ASD.

Concerning the relationship between amount of language exposure and language abilities, correlation analyses showed a similar relationship between these variables to that observed in typical development. Of particular interest, current amount of language exposure was the strongest predictor of scores on these standardized language tests of vocabulary and morphology. Furthermore, visual inspection of a scatterplot showed that to perform within the average range on receptive vocabulary measures, children with ASD and without language impairment needed to reach more than 40% of exposure to French, while for the expressive morphology measure more than 50% was required. These results are in line with those reported in a detailed study with TYP 5 year-old bilingual children (Elin Thordardottir, 2011) and highlight the importance of considering a child's amount of language exposure when interpreting a bilingual child's performance on standardized tests.

Findings from Study 1 also revealed that proficient bilingualism was not the outcome for all children with ASD who had histories of language exposure to an L2, but only for a subgroup of children. Therefore, when interpreting these results, the specific characteristics of our bilingual subgroup with ASD should be borne in mind -- that is, high-functioning children who are growing up in a context where bilingualism is supported societally and institutionally. If bilingualism is possible for children with ASD who have intellectual impairment and/or in other situations of bilingualism (e.g., where the second language is not valued similarly) needs to be investigated by further research.

Concerning findings from Studies 2 and 3, data indicated that bilingualism yielded some executive functioning advantages in children with ASD. More specifically, in Study 2, bilingual children with ASD outperformed their monolingual peers with ASD on a verbal fluency task, and their scores were not significantly different from those exhibited by TYP monolingual and bilingual children. Contrary to our predictions, superior set-shifting skills did not seem to be the mechanism driving this difference, as performance on the number of switches between sub-categories in the verbal fluency task was not significantly different across groups. Instead, enhanced generativity, as reflected in the number of total words produced, was hypothesized to better account for the difference found between bilingual and monolingual children with ASD.

Finally, in Study 3, results showed that bilingual children with ASD performed surprisingly well on the DCCS task, which assesses set-shifting skills, relative to monolingual children with ASD. Interestingly, this benefit was specific to set-shifting and was not found on a control executive function measure of verbal working memory. Yet, a parent report measure (i.e., BRIEF) concerning the use of executive functioning in daily life did not indicate a reliable set-shifting advantage in bilinguals relative to monolinguals with ASD. This measure did however confirm impairments in set-shifting skills for all children with ASD in comparison to TYP children. Overall, the results suggested that the set-shifting benefits found for the bilingual group with ASD may be limited to experimental paradigms.

Theoretical and Clinical Implications

Results from the current dissertation have implications for theories concerning language and cognition in ASD, as well as important clinical implications for children on the autism spectrum living in bilingual societies.

Concerning the language domain, our findings are in line with previous research suggesting that, to date, empirical evidence does not support limiting language exposure to one language only for children with ASD living in multilingual families or societies. Some children with ASD can become proficient bilinguals and can function in two languages. This finding has practical implications for interventions with children with ASD. For instance, given the relevance of parental involvement in early intervention for children with ASD (e.g., McConachie & Diggle, 2007), it can be argued that parents should be encouraged to use the language they feel more comfortable with to interact with their children. In addition, when assessing the language skills of bilingual children with ASD, clinicians should interpret assessment results in light of the relationship between language performance and amount of language exposure. That is, children should not be expected to perform in the average range on language measures unless they have adequate exposure (close to half of the time) to a given language. More importantly, professionals should inform parents about the effects that bilingualism might have in the language (e.g., performance on standardized tests closely related to current amount of language exposure) and executive functioning skills (e.g., enhanced performance on set-shifting experimental tasks) of children with ASD, providing realistic expectations.

In addition, if the current results are replicated in larger samples, and a bilingual advantage is observed on specific behaviours of children with ASD (e.g., enhanced set-shifting abilities or pragmatic skills), one might hypothesize that bilingual education could be recommended for some children with ASD to mitigate to some extent difficulties in some cognitive and language domains. However, this was not the case of the current findings, although these are potential venues for future work that need to be investigated carefully.

With respect to cognitive theories of ASD, findings from Study 2 and 3 only partially support the executive dysfunction theory of ASD. In line with this account, both groups with ASD were found to score within the executive dysfunction range on the BRIEF on the set-shifting sub-scale, suggesting impairments on daily life behaviours that require these skills. Nonetheless, deficits in set-shifting were not observed for bilinguals with ASD, but were for monolinguals with ASD on two experimental tasks: verbal fluency and the advanced version of the DCCS. We interpret this finding as a suggestion that bilingualism had a positive effect for children with ASD in these specific experimental paradigms. Accordingly, these results bring into question the executive dysfunction hypothesis as a *unitary* account of the cognitive profiles of individuals with ASD. More specifically, impairments were not universal for the ASD groups on either experimental tasks or daily life behaviours (e.g., working memory scores on the BRIEF did not reach the threshold for clinical significance in the ASD groups). Therefore, although *some* executive functioning skills are impaired in children with ASD, generalized executive dysfunction does not seem to be a core feature for all children on the autism spectrum.

Concerning the *bilingual advantage hypothesis*, our results were mixed. Advantages were observed on a verbal fluency task only for the bilingual group with ASD, reflecting enhanced generativity skills. We did not find reduced RTs in either the TYP bilingual group or the bilingual group with ASD on the DCCS task, contrary to results reported in studies on TYP bilingual children by Barac and Bialystok (2012) using a similar paradigm. However, the bilingual group with ASD showed significantly better accuracy on the computerized version of the DCCS relative to the monolingual group with ASD (as well as slower RTs commonly observed with a speed-accuracy trade-off). Though the laboratory task captured improved set-shifting accuracy in the bilingual ASD group, no significant differences were reported for their everyday behaviors encompassing set-shifting or working memory skills. Overall, in typical development, the bilingual advantage has been reported in experimental tasks for children, while cognitive benefits (e.g., late onset of dementia) have been found in bilingual adults (e.g., Bialystok, Craik, & Freedman, 2007; However, see Zahodne, Schofield, Farell, Stern, & Manly, 2014). It is possible that advantages on everyday behaviours are not observed given the young age of our bilingual groups. However, cognitive benefits might be observed later in life. Despite the controversy concerning the bilingual advantage hypothesis, it is undeniable that specific experiences, such as musical training, have effects on brain structures and functions (e.g., Münte, Altenmüller, & Jäncke, 2002), which is referred to as *neuroplasticity* (for a comprehensive review of neuroplasticity and bilingualism see Baum & Titone, 2014). Accordingly, it is highly probable that the experience of managing two linguistic systems across life have some particular implications for individuals with ASD. Yet, how bilingualism affects behaviour in this population is a topic that needs to be studied.

Limitations

Although the present dissertation makes an original contribution to the field of ASD by examining the language abilities of proficient bilingual children with ASD as well as testing the bilingual advantage hypothesis in this population, there are some shortcomings that need to be taken into consideration. The main limitation of the current studies is the small number of participants in our bilingual group with ASD. Despite our extensive efforts to recruit bilingual and monolingual children with ASD during a period of 2 years, this was a challenging process, given the specific criteria that children needed to meet to complete our experimental tasks (e.g., presence of verbal skills, NVIQ>80, etc). Yet, our results are based on a small but well-characterized sample of children with ASD, and in fact, significant differences on language and EF skills were found. The recruitment and assessment of a special population, as is the case of bilingual children with ASD, entails significant effort and time. Indeed, previous highly cited studies examining the language skills of bilingual children with neurodevelopmental disorders such as SLI (e.g., Paradis, Crago, Genesee, & Rice, 2003) and Down syndrome (e.g., Kay-Raining Bird et al., 2005) have had a similar sample size (e.g., 8 participants) in their bilingual group to the sample in the current project.

Another limitation of this dissertation is the generalisation of results to other groups of children with ASD. The profile of the bilingual and monolingual children included in this set of studies was very specific. That is, our participants with ASD were high-functioning children who had superior or average nonverbal cognitive abilities. Furthermore, all of them had phrase-level speech, and were able to complete most of the tasks presented in our protocol. In addition, the context in which the present dissertation took place, Montreal, Canada, is highly supportive of bilingualism, which presented the perfect scenario for the development of this dissertation. Hence, results from the present studies cannot be generalized to all children with ASD, or situations of bilingualism.

Finally, the number of tasks used to assess some of the constructs of interest was reduced, given the broad range of measures gathered for the present studies (i.e., NVIQ, executive functioning, language measures, etc.). Future studies should focus on one specific domain (e.g., pragmatic skills) and gather multiple measures that provide information of that specific ability in different contexts.

Future Directions

This dissertation has provided novel evidence concerning the linguistic and cognitive abilities of bilingual and monolingual children on the autism spectrum. Notwithstanding these important contributions, further studies should be undertaken to extend the current findings to other children on the autism spectrum (e.g., children with NVIQ <80, receptive bilinguals, children with exposure to languages other than English and French, older children, etc.).

Furthermore, findings from Study 1 revealed that *proficient bilingualism* was not the outcome for all children with ASD who had histories of language exposure to an L2. Almost half of our potential bilingual participants did not have or had limited expressive skills in their L2. While this outcome can be explained by low amounts of language exposure to an L2 for some children, for others this was not the case. Of interest, this result seems to differ to some extent to what is found in TYP children, where regularly, history of language exposure strongly predicts language performance. Therefore, more research is needed to determine the specific factors, beyond language exposure, that predict the acquisition and use of an L2 in this population.

Regarding the relationship between bilingualism and language abilities, the scope of this study was limited to two language domains, namely, vocabulary and morphology and lexical-semantic skills. A further study could assess other language spheres such as pragmatic abilities. Specifically, it would be interesting to explore whether bilingualism confers some pragmatic benefits, given the characteristic difficulties exhibited by individuals with ASD in this domain. For instance, previous research has reported that TYP bilingual pre-school children outperformed their monolingual peers on theory of mind tests such as perspective-taking and false belief tasks (Goetz, 2003). However, this hypothesis has not been investigated in bilingual children with ASD. This would be a fruitful area for future work.

In addition, further experimental investigations are needed to examine the relationship between set-shifting skills and conversational code-switching. Evidence concerning the effects of code-switching on executive functioning skills is mixed, with some studies reporting that higher amounts of code-switching in daily life result in superior performance on set-shifting tasks such as verbal fluency (Yim & Bialystok, 2012) and other non-verbal executive functioning paradigms (Verreyt, Woumans, Vandelanotte, Szmalec, & Duyck, 2016). Yet, this relationship has not been found in other studies (e.g., Paap et al., 2016). Accordingly, this relationship warrants study in individuals with ASD to better understand the mechanisms of any potential bilingual advantage.

Conclusion

The current dissertation makes a novel contribution to our understanding of the effects of bilingualism on the linguistic and cognitive skills of school-age children with ASD. Findings from the present set of studies suggest that bilingualism can have divergent effects on language performance and executive functioning skills in high-functioning children with ASD.

Although not presenting delays, bilingual children with ASD tended to exhibit lower scores relative to their monolingual peers with ASD on standardized measures of vocabulary, which is likely explained by the relationship between amount of language exposure and language proficiency (Elin Thordardottir, 2011). No significant differences between these groups were found on a standardized test of morphological ability. We provided novel evidence that bilingualism may hold advantages for executive functioning in some children with ASD. This was found in two experimental paradigms (i.e., verbal fluency task and DCCS task), but not for parent report of set-shifting in daily life. These findings build on previous research suggesting that bilingualism is not detrimental for the language abilities of children with ASD and in fact may provide some advantages in experimental paradigms that encompass set-shifting skills. More important, it should be borne in mind that bilingualism provides some social advantages such as the possibility to interact with multiple speakers and to be part of more than one culture. Thus, the possibility for children with ASD to grow up in a bilingual environment, instead of limiting the numbers of languages they are exposed too, should be considered as a favorable option for children on the autism spectrum who are part of a bilingual family or society.

9. General References

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10. Appendix

Parent Questionnaire
Child's Language Exposure

Participant ID: _________ Gender: M ___ F ___ Language exposure: Monolingual ___ Bilingual ___

D.O.B: _____________________________ Age: ___________________ Date of testing: ______________

Please fill out the following information:

Child's Current Language Use	**Language 1**	**Language 2**	**Language 3**	**Language 4**
1. What language or languages are spoken at home?				
2. What language(s) does the mother use to communicate with the child?				
3. What language(s) does the father use to communicate with the child?				
4. What language(s) do the siblings use to communicate with the child?				
5. If the child lives with other relatives, what language(s) is (are) used for them to communicate with the child?				
6. What language(s) does the child use when speaking with friends?				
7. What language(s) are spoken at school?				
8. In what language(s) does the child watch television?				
9. In what language(s) does the child listen to music?				
10. In what language(s) does the child play videogames (Ipad, Wii, etc.)?				
11. If you read books to your child, in which language(s)?				
12. If your child reads books, in which languages he/she reads?				

13. How often do you read to your child (times per week)?

0	1	2	3	4	5	6	7 or more

14. Please estimate how often your child currently hears each language per week (from Monday to Sunday), including all settings (home, school/daycare, and other activities). Do not include the hours when the child is asleep

	Language 1	**Language 2**	**Language 3**	**Language 4**
Total hours per week				

Child's Language History	**Language 1**	**Language 2**	**Language 3**	**Language 4**
15. At what age was your child first exposed regularly to the language(s) he/she speaks?				
Birth – 1st year				
16. If your child attended daycare at this age, which language(s) was used in the daycare?				
17. What language(s) was used at home at this age?				
18. Could you estimate how often your child heard each language per week, including all settings (such as home, relatives, and daycare)? For example, 70% of the time English, 30% of the time French.				
1st – 2nd year				
19. If your child attended daycare at this age, which language(s) was used in the daycare?				
20. What language(s) was used at home at this age?				
21. Could you estimate how often your child heard each language per week, including all settings (such as home, relatives, and daycare)? For example, 70% of the time English, 30% of the time French.				
2nd – 3rd year				
22. If your child attended daycare at this age, which language(s) was used in the daycare?				
23. What language(s) was used at home at this age?				

24. Could you estimate how often your child heard each language per week, including all settings (such as home, relatives, and daycare)? For example, 70% of the time English, 30% of the time French.				
3rd – 4th year				
25. If your child attended daycare at this age, which language(s) was used in the daycare?				
26. What language(s) was used at home at this age?				
27. Could you estimate how often your child heard each language per week, including all settings (such as home, relatives, and daycare)? For example, 70% of the time English, 30% of the time French.				
4th – 5th year				
28. If your child attended daycare at this age, which language(s) was used in the daycare?				
29. What language(s) was used at home at this age?				
30. Could you estimate how often your child heard each language per week, including all settings (such as home, relatives, and daycare)? For example, 70% of the time English, 30% of the time French.				
5th – 6th year				
31. If your child attended daycare at this age, which language(s) was used in the daycare?				
32. What language(s) was used at home at this age?				
33. Could you estimate how often your child heard each language per week, including all settings (such as home, relatives, and daycare)? For example, 70% of the time English, 30% of the time French.				
6th – 7th year				
34. If your child attended daycare at this age, which language(s) was used in the daycare?				

35. What language(s) was used at home at this age?				
36. Could you estimate how often your child heard each language per week, including all settings (such as home, relatives, and daycare)? For example, 70% of the time English, 30% of the time French.				
7^{th} – 8^{th} year				
37. If your child attended daycare at this age, which language(s) was used in the daycare?				
38. What language(s) was used at home at this age?				
39. Could you estimate how often your child heard each language per week, including all settings (such as home, relatives, and daycare)? For example, 70% of the time English, 30% of the time French.				

Child's Current Language Proficiency

Please rate your child's proficiency in each language he/she speaks:

Language 1: ____________________

Speaking Excellent ___ Good ___ Gets by ___ Limited ___

Listening Excellent ___ Good ___ Gets by ___ Limited ___

Language 2: ____________________

Speaking Excellent ___ Good ___ Gets by ___ Limited ___

Listening Excellent ___ Good ___ Gets by ___ Limited ___

Language 3: ____________________

Speaking Excellent ___ Good ___ Gets by ___ Limited ___

Listening Excellent ___ Good ___ Gets by ___ Limited ___

Language 4: ____________________

Speaking Excellent ___ Good ___ Gets by ___ Limited ___

Listening Excellent ___ Good ___ Gets by ___ Limited ___

Comments:

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