FACTORS AFFECTING EXECUTIVE FUNCTION IN CHILDREN WITH AUTISM SPECTRUM DISORDER

by

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Abstract

In typically developing children, better performance on tasks of executive function (EF) is associated with bilingualism as well as participation in activities that engage EF, such as playing video games, attending music lessons, and getting regular exercise. Furthermore, activities found to improve EF abilities tend to be most effective in participants with lower EF at baseline. Children with Autism Spectrum Disorder (ASD) often have deficits in EF. With the prevalence of ASD on the rise, research on the factors contributing to EF development in children with ASD is crucial for the advancement of evidence-based practice for professionals working with these children. This study aims to address whether children with ASD experience EF benefits from dual language exposure and participation in EF-supporting activities.

This study's sample was comprised of ten children with ASD, aged six to ten years. Participants were divided into groups based on whether they were primarily exposed to one or two languages, and based on whether they played video games, attended music lessons, or engaged in fitness activities. Each participant was tested on two tasks of inhibition (Simon and flanker tasks) and two tasks of visuospatial working memory (forward- and backward-span). Language exposure group differences were found, but not in conditions that target EF abilities. The only group difference specific to conditions with EF involvement was in favour of children who engage in regular physical fitness. While these results do not support dual language exposure, video game playing or musicianship as EF supporting experiences, the results of this study are limited by the small sample size. In addition to group comparisons, data from three participants is discussed within the context of development of EF in children with ASD.

Lay summary

Executive functions (EF) are the set of mental skills that allows us to behave in a goal-directed manner. Previous research has found that children who speak and understand more than one language have advantages in EF over those who only use one language. Similarly, children who play video games, play musical instruments, and exercise regularly have been found to have advantages in EF compared to children who do not engage in these activities. In this thesis, a group of ten children with autism spectrum disorder was tested on a number of EF tasks. The participants were grouped based on how many languages they are exposed to in their daily life, and whether or not they participate in video gaming, musicianship, or regular exercise. There were no EF differences based on language exposure, video gaming or musicianship; however, the group who exercised demonstrated better EF skills on one of the tasks.

Preface

The study described in this thesis was approved by The University of British Columbia's Behavioural Research Ethics Boards (#H16-01232). Two amendments to the original application were also approved (#H16-01232-A001, #H16-01232-A002).

The research problem addressed by this thesis was jointly identified by the author, S. L. Siroski, and the thesis supervisor, S. Marinova-Todd. The study was primarily designed by the author, with contributions from S. Marinova-Todd. The data collection and analysis were the sole responsibility of the author.

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Dedication

This work is dedicated to my late grandparents: Henry and Maizie, Ken and Shirley.

1. Introduction

Executive functioning (EF) refers to a set of cognitive skills that make it possible to accomplish goal-directed tasks (Best & Miller, 2010). This set of skills is especially needed when the task requires conscious and controlled information processing (Diamond, 2012; Zelazo & Müller, 2010). EF skills are needed in order to accomplish many of the tasks required of adults and children in their everyday lives. It is the EF system that allows a student to do their math homework instead of watching cartoons, to follow multi-step instructions in the classroom, and to switch from math class to science class without confusion or distraction. These everyday situations illustrate the three components of EF, respectively: inhibition, working memory, and shifting. In addition to helping us accomplish isolated tasks, EF skills in children also contribute to the development of social communication abilities (Blain-Brière, Bouchard, & Bigras, 2014) and school readiness and success (Diamond, 2012; Blair & Razza, 2007). In adults, EF skills are linked with having a happy marriage, maintaining physical fitness and health, and achieving a high quality of life (Diamond, 2012).

Given the far-reaching impact of EF, it is no surprise that much research has been dedicated to finding ways to improve EF skills in children and adults. Some studies have looked at the impact of commerciallyavailable video games (Bialystok, Martin, & Viswanathan, 2005; Powers, Brooks, Aldrich, Palladino, & Alfieri, 2013), music training (Bialystok & DePape, 2009; Degé, Kubicek, & Schwarzer, 2011; Moradzadeh, Blumenthal, & Wiseheart, 2015), and aerobic exercise (Davis et al., 2007; for review, see Best, 2010). These lines of research all have the same reasoning in common; these activities engage some aspect of EF, working it like a muscle. The more one engagement in activities with high EF demands, the more “practise” one has in using these skills. Furthermore, researchers have found that individuals with low EF skills at baseline are those who tend to have the greatest benefit from EF-supporting experiences (Flook et al., 2010; Karbach & Kray, 2009).

There is one activity that requires significant use of EF that can be practised all day long: bilingual communication. In an impressive feat of multi-tasking, bilingual individuals keep both of their languages active during tasks of comprehension and speech production (for review, see Kroll, Dussias, Bogulski, & Valdes Kroff, 2012). Language selection is done by inhibiting the language that is not in use (Green, 1998). The demands of managing these two (or more) languages while completing everyday communication tasks engages EF (for review, see Bialystok, Craik, Green, & Gollan, 2009). With bilinguals constantly making use of EF, we would expect to find differences between them and their monolingual peers on tasks that measure EF. These differences have indeed been identified in children (e.g., Martin-Rhee & Bialystok, 2008; Morales, Calvo, & Bialystok, 2013) and adults (e.g., Bialystok, Martin, et al., 2005; Prior & MacWhinney, 2010); however, this *bilingual advantage* has not always been replicated, with several studies failing to find differences between monolinguals and bilinguals on measure of EF (e.g., Paap & Greenberg, 2013).

One group of individuals who could benefit from improved EF skills are clinical populations that commonly experience EF deficits, such as people with Autism Spectrum Disorder (ASD). EF deficits have been identified in children with ASD (Geursts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004) and have been implicated as a core deficit in this population (Ozonoff, Pennington & Rogers, 1991; Russell, 1997). To date, there is no published research looking at the impact of bilingual language exposure on the EF of children with ASD, and little research looking at the impact of video gaming, musicianship, and exercise. Given that this is a population that typically experiences EF deficits, one would expect to see a larger impact of these EF-improving experiences than what is seen in research on typically developing (TD) children. This is the hypothesis at the heart of this exploratory study. This thesis begins with a review of the literature related to EF, bilingualism and EF-supporting activities, and ASD, followed by a description of the methods of this study, and concludes with the presentation and discussion of the results.

1.1. Executive functioning

As previously defined, EF refers to a set of cognitive functions that are required when one is working to accomplish a goal which requires conscious controlled processing (Best & Miller, 2010; Diamond, 2012; Zelazo & Müller, 2010). The currently dominant theory of EF is Miyake, Friedman and colleagues' (2000) framework of unity and diversity of EF systems. These authors used a latent variable approach where they examined the task performance overlap between related tasks of EF in adults. They found that popular tasks used to measure EF had some overlap, but also required unique factors to explain performance differences. The model produced based on the data could best account for the results with three factors present, which the authors identified as *Shifting*, *Updating*, and *Inhibition*. *Shifting* is defined as the ability to switch flexibly between mental sets or tasks, *updating* is defined as the ability to add to, delete from, and monitor the contents of working memory, and *inhibition* is defined as overriding dominant information or responses. These factors themselves were highly correlated with each other (i.e., unity) but also individually accounted for a significant amount of variation between tasks (i.e., diversity).

More recently, Miyake and Friedman (2012) described that the unity of EF subsystems can be described as a *common EF* ability that works in conjunction with subsystem-specific abilities to produce task performance. For example, on a task that measures *shifting*, performance is determined by the participant's *common EF* ability plus their *shifting*-specific abilities. The authors also found that this *common EF* ability accounts for all of the contributions of the *inhibition* factor. The revised framework replaces *inhibition* with *common EF*, defining it as one's ability to maintain activation of a task goal and influence lower-level processes in order to achieve this goal. One could consider this to be simply a different perspective on inhibition (i.e., activation of task-relevant information versus inhibition of task-irrelevant information), especially considering that this *common EF* factor has been correlated with levels of behavioural inhibition (Young et al., 2009). Furthermore, developmental differences in EF have been identified, where *inhibition* does not overlap with the *common EF* factor in children as it does in adults (Huizinga, Dolan, & van der Molen, 2006). Given the additional consideration that, to date, the *common EF* ability has not replaced the term 'inhibition' in EF literature, this paper will continue to use the term 'inhibition' when describing tasks where the participant must override a dominant response.

There is some evidence that inhibition may require further subdivision. Christ, Holt, White, and Green (2007) studied a group of children with ASD and had them perform three tasks of inhibition: two Stroop tasks and a flanker task. A Stroop task (Stroop, 1935), in its most basic form, uses a colour word (e.g., BLUE) which is printed in either the same colour as the word (e.g., blue) or a different colour (e.g., red). The participant must verbally respond with the colour *of* the word and not the colour word that is printed. The basic form of the flanker task (Eriksen & Eriksen, 1974) uses a centrally-presented arrow which is flanked by distractor arrows. On some trials, the flanker arrows point in the same direction as the centrally-presented target arrow (e.g., < < < < <), while on other trials, the flanker arrows point the opposite direction (e.g., > > < > >). The participant must indicate the direction of the central target arrow. In both tasks, the participant must inhibit distracting information (i.e., printed word; flanker arrow directions) while attending to target information (i.e., colour of the word; central arrow direction). In both of these tasks, participants generally make more errors and have slower response time (RT) when the distracting information is incompatible with the target information, and make fewer errors and have faster RT when they are compatible. However, the participants in Christ et al. (2007) performed comparably to a control group on the Stroop tasks, but performed worse than the controls on the flanker task. In other words, they had different profiles of performance between these two tasks that are purported to target the same EF ability. Similarly, using confirmatory factor analysis on the performance of a sample of TD seven- to twenty-one-year-olds, Huizinga et al. (2006) found that the Stroop task and the flanker task loaded onto different *inhibition* variables as opposed to loading onto the same factor.

Paap and Greenberg (2013) looked at the performance of young adults on the flanker task and another task of inhibition, the Simon task (Simon task; Simon & Rudell, 1967). In the Simon task, the participant is seated at a computer and told to press the left key when they see a blue square and to press the right key when they see a red square. The squares are presented on either the left or right side of the screen. When the location of the square matches the side with the correct button (e.g., red square on the right side of the screen), this is a congruent trial, and participants are generally more accurate and faster at responding to these trials. When the location of the square and the correct button do not correspond (e.g., red square on the left side of the screen), this is an incongruent trial, and participants generally make more errors and have slower RT to these trials. Once again, although these are both considered tasks of inhibition in the literature, the participants' performance on these tasks did not correlate with each other.

The finding of discrepant performance on these tasks is not isolated, and given the evidence that these tasks do not target the same cognitive skill, a distinction will be made between two types of tasks for the purposes of clarity in reviewing the EF literature. It is the view of the author that the primary distinction between these tasks is that in the Stroop task and Simon task, the distracting information is intrinsic to the target stimulus. That is, in the Simon task for example, in order for a participant to determine the colour of the square, they must *necessarily* locate the square on the screen and therefore attend to the distracting spatial information. On the other hand, in the flanker task, distractors are extrinsic to the target stimulus. In order for a participant to identify the direction of the target arrow, it is not *necessary* to encode the direction of the flanker arrows. Therefore, the distinction will be made between tasks of intrinsic inhibition (i.e., Simon task or Stroop task) and tasks of extrinsic inhibition (i.e., flanker task).

1.1.1. Development of EF

Rudimentary EF skills begin to emerge by the end of the first year of life (Diamond, 2002). Using a task in which infants must repeatedly retrieve a toy hidden in location *A*, but must change their retrieval strategy once the experimenter switches to hiding the toy in location *B*, researchers have found that by the end of their first year, most infants can successfully find the toy on the first post-switch trial (Diamond, 2002). Researchers have also used a task in which an infant must retrieve a toy from a clear plastic box, but must inhibit the urge to reach through the solid front of the box, as the only way to access the toy is actually through a hole on the side of the box. Infants between six and eight months of age will attempt to reach through the front of the box, but infants eleven to twelve months easily adapt to reaching around the side of the box after observing an adult do so (Diamond, 2002).

While EF skills continue to develop throughout the toddler years, the most significant advancement in EF skills does not occur until the period between approximately three to seven years of age (Diamond, 2002). Inhibition and working memory are already differentiated by the preschool years (Best & Miller, 2010). One way in which researchers can see development of inhibitory skills is in the trade-off between RT and accuracy on EF tasks. For example, in the day-night Stroop task, a child is presented with either a picture of a sun or a moon. The participant is instructed to respond with “day” when presented with the moon and to respond with “night” when presented with the sun. According to Diamond (2002), when four-year-old children are tested on this, they struggle to inhibit the semantically appropriate response (i.e., responding “night” to the picture of the moon) and will display a pattern of fast RT and low (approximately 50%) accuracy. Interestingly, when the experimenter imposes a “wait-time” before the child can respond, the performance of this younger group improves significantly, reaching almost 90% accuracy. Children at the later stages of EF development (six to seven years) achieve close to 100% accuracy without needing the imposed “wait-time”; instead, they spontaneously delay their responses in order to achieve higher accuracy. This demonstrates how children in the early stages of EF development *respond* faster than they are able to *inhibit*. External “wait-times” allow inhibition to catch up with their impulse to respond and generate the correct response. In comparison, older children *inhibit* faster than they *respond*, allowing them to provide the correct response without external support.

There is mixed evidence regarding development of inhibition after the age of seven, with some research finding relative stability during the school-age years and others finding further development, particularly in the area of behavioural inhibition (Best & Miller, 2010). Adolescence appears to be a second burst of development in EF. Huizinga et al. (2006) found improvement on tasks of extrinsic inhibition until the age of fifteen, and further improvements on a task of intrinsic inhibition until around age twenty-one.

Executive working memory develops through the school-age years, with low EF-demand (i.e., storage and recall of information) task improvements levelling off by the age of nine and high EF-demand (i.e., storage, recall and manipulation of information) task improvements continuing into young adulthood (Best & Miller, 2010). The content of working memory does not appear to affect development, with both verbal and spatial working memory following similar developmental courses (Conklin, Luciana, Hooper, & Yarger, 2007). As opposed to the periods of rapid development seen in inhibition, working memory development appears more constant, with Best and Miller (2010) reporting a steady improvement in performance on tasks of working memory between the ages of four and fourteen.

Shifting, on the other hand, does not appear to be differentiated from inhibition and working memory until children achieve a minimum competency in those areas. Best and Miller (2010) hypothesize that this may be because shifting requires the child to keep one mental set in mind while temporarily inhibiting another mental set. Huizinga et al. (2006) examined the developmental trajectory of “switch cost,” or how much extra time it takes to respond to a trial when the required response is different than the response to the previous trial. Higher switch costs indicate less efficient shifting abilities. They found that seven- and eleven-year-olds had higher switch costs compared to fifteen-year-olds, who performed at adult levels.

The development of EF is not only seen in these rigid, EF-targeting tasks, but also in children's development in other areas. In a study of four- and five-year-old children, Blain-Brière et al. (2014) found that EF contributed to the development of social communication skills more than IQ. Children with more developed inhibition skills were less inappropriately talkative, and those with more developed working memory were more likely to provide appropriate responses to questions. On the other hand, children with deficits in EF may exhibit behaviours that are impulsive (i.e., poor inhibition), may have difficulties planning actions or organizing information (i.e., poor working memory), or may appear rigid and have difficulty changing their behaviour (i.e., poor shifting) (Anderson, 2002).

Young adulthood is a period of stability and peak performance with regard to cognitive testing (Bialystok, Martin, et al., 2005). Later in life, however, there is natural deterioration of the frontal lobe structures and an associated decline in EF abilities (Zelazo, Craik, & Booth, 2004). Many studies have found that, compared to young adults, older adults have poorer performance on tasks that target EF abilities. Bialystok, Martin, et al. (2005) found that older adults (age range = 60-80 years) had slower RT on the Simon task compared to middle-age adults (age range = 30-59 years). Zelazo et al. (2004) compared children (age range = 8.2-9.5 years), young adults (age range = 19.5-26.6), and older adults (age range = 65.8-74.2) on complex EF tasks that primarily targeted shifting abilities. They found that performance on the tasks followed a U-shape pattern across the groups, with young adults achieving higher performance than both the children and the older adults. Bialystok, Craik, &

Luk (2008) found effects of aging on several tasks of EF, including working memory. Aging-related decline in EF abilities appears to affect all EF sub-systems.

1.1.2. Atypical development of EF

Developmental differences in EF have been proposed as central deficits in certain developmental disorders, particularly attention deficit hyperactivity disorder (ADHD) and ASD. In order to address the issue of discriminant validity (i.e., two different disorders should not be attributable to the same central deficit), researchers have investigated the unique EF profiles for ADHD and ASD. In general, researchers have found that children with ADHD have more significant deficits in inhibition, whereas children with ASD have more significant deficits in shifting (Ozonoff & Jensen, 1999; Geurts et al., 2004). However, researchers have also found that the EF deficits in ASD are more pervasive than in ADHD, affecting all subsystems to a certain degree (Geurts et al., 2004).

Children with ASD, although generally less impaired in inhibition compared to children with ADHD, tend to perform poorly compared to TD controls on tasks targeting this subsystem. While several studies found that children with ASD perform at the same level as TD controls (Geurts et al., 2004; Goldberg et al., 2005; Ozonoff & Jensen, 1999; Russell, Jarrold, & Hood, 1999), other studies have found that children with ASD perform more poorly on tasks of intrinsic inhibition (Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009; Verté, Geurts, Roeyers, Oosterlaan, & Sergeant, 2005). Studies using tasks of extrinsic inhibition have found that children with ASD perform worse than TD controls (Adams & Jarrold, 2012; Christ et al., 2007). Behavioural inhibition (i.e., the ability to inhibit a motor response) has mixed findings, with some studies finding poorer performance for children with ASD compared to TD controls (Christ et al., 2007; Geurts et al., 2004; Ozonoff, Strayer, McMahon & Filloux, 1994; Verté et al., 2005) and others finding no differences (Adams & Jarrold, 2012; Happé, Booth, Charlton, & Hughes, 2006; Kana, Keller, Minshew, & Just, 2007; Ozonoff & Strayer, 1997).

In general, working memory is found to be impaired in children with ASD. In a review of memory function in the ASD population, Boucher, Mayes, and Bigham (2012) found that tasks that require only information storage and recall are generally unimpaired in children with ASD; however, when tasks require information storage, recall *and* manipulation, the findings are mixed but appear to be related to task difficulty and age. Goldberg et al. (2005) studied children aged eight to twelve years and found tasks targeting spatial working memory with high EF demands (i.e., information manipulation) to be the only EF tasks where children with ASD have lower performance compared to TD controls. Furthermore, Happé et al. (2005) found that only the younger group of children with ASD (age range = 8-10 years) showed spatial working memory deficits compared to TD controls; the older ASD group (age range = 11-16 years) had equivalent performance to TD controls. Deficits also appear to be more prevalent in spatial working memory tasks compared to verbal working memory tasks (Boucher et al., 2012). Williams, Goldstein, Carpenter, and Minshew (2005) compared children, adolescents, and adults with ASD to TD controls of the same age and found no deficits at any age for verbal working memory, but deficits at all ages for spatial working memory.

Finally, shifting appears to be generally impaired in children with ASD. Many studies have found that children with ASD perform worse on the Wisconsin Card Sorting Task (WCST; Grant & Berg, 1948) compared to their TD peers (Geurts et al., 2004; Ozonoff & Jensen, 1999; Pellicano, 2010; Robinson et al., 2009; Verté et al., 2005). In this task, the participant must sort a deck of cards along one of three dimensions (i.e., by colour, shape, or number) based on corrective feedback from the experimenter. The participant is never explicitly told the sorting rule; they must infer it based on the feedback they receive. After a certain threshold of performance is achieved on one dimension (e.g., sorting by colour), the sorting rule is switched to target a different dimension (e.g., sorting by shape). The participant must use the feedback from the experimenter to infer the new rule and shift to sorting according to this new rule. Although this task has been found to be associated with the shifting subsystem (Miyake et al., 2000), some authors insist that it is a better indicator of inhibition or is too complex to be considered a task targeting a single EF component (Best & Miller, 2010). Goldberg et al. (2005) and Happé et al. (2006) also investigated shifting in addition to working memory and inhibition, and neither study found shifting deficits in the participants with ASD compared to age-matched peers without ASD. However, both of these studies used tasks other than the WCST, indicating that perhaps the investigation of the shifting subsystem would benefit from the use of multiple measures, similar to inhibition. Overall, there is evidence that children with ASD exhibit deficits in all three EF sub-systems relative to their TD peers.

1.1.3. Environmental influences on EF development

Several studies have found that children from low socioeconomic status (SES) backgrounds have a relative disadvantage in EF skills compared to their peers from higher SES backgrounds. Sarsour et al. (2011) found that children from low-SES backgrounds, particularly when raised in single-parent households, showed lower performance on tasks of inhibition and shifting compared to children from mid- or high-SES backgrounds. Likewise, Farah et al. (2006) found that SES differences were significantly related to differences in working memory and inhibition. While the association is striking, Farah et al. (2006) point out that low-SES upbringing is likely not the cause of reduced EF abilities, but that various other factors associated with low-SES upbringing such as poorer nutrition and higher stress may be influencing EF development.

The cultural context in which a child is raised may also have an impact on their EF development. Yang, Yang, & Lust (2011) found that children living in Korea performed better on a flanker task compared to both Korean-speaking monolingual children and English-speaking monolingual children in the United States. Lewis et al. (2009) reviewed the EF findings comparing children in Korean, Japanese, and Chinese cultures to children in the West. The general finding is that the children in Korean, Japanese, and Chinese cultures had better performance on EF tasks compared to Western children. The explanations for these differences are varied – genetics, parenting styles, early education policies – and none have conclusive evidence to support them.

While factors such as SES and culture are difficult for any individual to control within their own life, there are experiences that one can seek out that may impact EF skills. Participation in certain activities may positively influence the development of EF abilities. These activities include playing video games, playing a musical instrument or singing, and participating in regular exercise.

1.1.3.1. Video games

A few studies have examined the impact of playing video games on the EF development of children. Some used computer games specifically designed to train EF skills. For example, Mackey, Hill, Stone and Bunge (2011) had seven- to nine-year-old children play a video game that targeted either increasing RT speed or improving reasoning skills.

They found that children generally improved in the area targeted by the game, but that there were no cross-over effects.

Other studies have investigated the effects of commercially available games on EF. Commercially available video games, although not designed to target EF skills specifically, often call on the same skills targeted by EF tasks, such as inhibiting irrelevant information, keeping multiple objectives in mind simultaneously, and switching goals or mental sets based on new information. Staiano, Abraham, and Calvert (2012) studied the combined impact of exercise and video games on EF, using a popular "exergame". The exergame requires that the participant use imitative gross motor movements to move the controllers in order to play the games (e.g., powerful arm swings to play a tennis game; rapid punching movements to play a boxing game). The adolescent participants in this study were assigned to either a competitive, cooperative, or no-play condition. Only the participants in the competitive condition improved on their scores on an assessment of EF, indicating that the improvement was associated with the increased cognitive demand in the competitive condition, and not just increased exercise in both the competitive and cooperative conditions. Studies of adults have likewise found EF improvements in video-gamers compared to non-gamers (Bialystok, 2006; Bialystok, Martin, et al., 2005).

In a meta-analysis of research on video game experience and cognitive abilities, Powers et al. (2013) found that across all ages and types of video games, the impact of video game experience was significantly associated with improvements in EF skills, although effect sizes ranged from very small to small. The authors also found that when quasi-experimental and truly experimental designs were analyzed separately, only quasi-experimental designs supported the link between video games and EF. It is suggested that this may be due to a selfselection participation bias, wherein those with greater EF skills may be more inclined to play video games, and, in turn, may be more likely to participate in research where they can "represent" their hobby. However, it should be noted that time spent playing video games is likely confounded with the experimental/quasi-experimental split, with quasi-experiments being more likely to involve participants who have played video games habitually for a long time, while experiments typically have participants playing for a shorter period of time. Whereas one quasi-experimental study put the minimum threshold for the video game players at six hours of gaming per week for the last six months (i.e., at least 156 hours; Strobach, Frensch, & Schubert, 2012), the longest experimental training time reported in Powers et al. (2013) was 50 hours. Overall, there is evidence, but no consensus as of yet, that playing video games improves EF.

1.1.3.2. Musicianship

Musicianship has also been associated with EF differences in children and adults. The experience of playing music engages the core components of EF: the musician must selectively attend to their part in a multi-part ensemble, keep their teacher or conductor's feedback in mind during rehearsal, and switch between styles of playing. Degé et al. (2011) assessed nine- to twelve-year-old children on various measures of EF and found that 12-20% of the variance in each task could be explained by time spent in music lessons. They interpreted this as supporting the association between playing music and development of EF skills. In adults, Bialystok and DePape (2009) studied a sample comprised of monolinguals and bilinguals, and musicians and non-musicians. They found that on a visual task of intrinsic inhibition, the bilinguals outperformed the monolinguals and the musicians outperformed the non-musicians. However, on an auditory task of intrinsic inhibition, the musicians outperformed both the bilingual and the monolingual non-musicians. This finding suggests that while the bilingual group may have EF advantages in the area of visually-presented inhibition tasks, the musicians had advantages in both visually- and aurally-presented tasks. Moradzadeh et al. (2015) extended the findings of improved EF in musicians to include the subsystem of shifting.

1.1.3.3. Exercise

Physical exercise, in addition to having a positive impact on overall physical health, also positively contributes to EF skills. Exercise requires that sequences of motor actions be planned and carried out in order to accomplish a goal, engaging multiple components of EF (Davis et al., 2007). In a randomized control trial, Davis et al. (2007) assigned overweight seven- to eleven-year-old children to either a high-dose exercise, low-dose exercise, or control group. Both dosage groups showed improvements on tasks that target EF, and did not show improvement on tasks that do not target EF. The authors interpret this finding as supporting a positive impact of aerobic exercise that is specific to EF skills. In a review, Best (2010) cited evidence for both the acute effects of individual exercise sessions on EF abilities, but also the lasting impact of long-term physical activity participation towards EF improvements.

Two studies have investigated the impact of exercise of the EF of clinical populations with EF deficits. List Hilton et al. (2014) conducted a pilot study investigating the impact of a non-competitive exergame on several EF and motor measures in school-age children with ASD. They found that after playing the game for thirty sessions (each session only lasting two minutes), the participants showed improvement on measures of working memory compared to their pre-intervention scores. Chang, Liu, Yu, and Lee (2012) investigated the acute effects of exercise on EF in children with ADHD and found that exercise led to improvements on the Stroop task (i.e., a task of intrinsic inhibition) and the WCST (i.e., a task of shifting). These studies indicate that exercise may be supportive of EF skills in clinical populations.

1.1.3.4. Interaction with baseline EF

Along with investigating the impact of various types of experiences on EF, researchers in this area have also investigated whether the impact of this EF training is equal for all individuals. Studies have demonstrated that EF training is more effective for those with the most to gain -- that is, individuals with less developed EF skills at baseline often show the most improvement when given the opportunity to practice and hone these skills (Flook et al., 2010; Karbach & Kray, 2009). This finding highlights the potential for EF training to be used to provide a much needed boost for individuals with EF deficits, such as children from low SES backgrounds, aging adults, and children with deficits in EF, such as those with ASD or ADHD.

1.2. Bilingualism

Historically, research comparing monolinguals and bilinguals tended to find lower intelligence in bilinguals (Romaine, 1995: 108-111). Early studies on bilingualism in North America used newly developed English-language intelligence tests and did not account for the fact that, often, the bilingual participants were new immigrants to North America and may not have had a high degree of proficiency in English. This ‘deficit’ view of bilingualism was widely accepted in North America until Peal and Lambert (1962) published the results of a seminal research study that employed rigorous controls for other variables that were known at the time to be associated with intelligence, including SES, sex, age, and quality of education. The results indicated that the bilingual group either matched or performed better than the monolingual group on all measures of intelligence that were used. Further analysis revealed that the bilingual group outperformed the monolingual group specifically on nonverbal intelligence tasks that required mental manipulation of information.

1.2.1. Effect of bilingualism on EF

Since Peal and Lambert (1962), many studies have found that bilinguals outperform their monolingual peers on tasks of inhibition, working memory and shifting (for a meta-analysis, see Adesope, Lavin, Thompson, & Ungerleider, 2010). The initial explanation for bilingual advantages in EF was based on the theory of linguistic inhibition. Psycholinguistic research had found that bilinguals maintain activation of both of their languages, and that during communication tasks, they select one of their languages by inhibiting the non-selected language (Green, 1998; Kroll et al., 2012). There is evidence that this inhibition of the non-target language occurs in both tasks of verbal production (Kroll, Bobb, Misra, & Guo, 2008) and auditory comprehension (Marian & Spivey, 2003; Spivey & Marian, 1999). In order to overcome the processing burden during communication, bilinguals must develop more efficient inhibition abilities so as to match the resources available to those who do not have this additional burden (i.e., monolinguals). This viewpoint was supported by early research findings indicating that bilinguals outperformed monolinguals in tasks of inhibition (for review, see Bialystok, 2001).

Subsequent research found that not only did bilinguals outperform monolinguals on tasks that targeted inhibition, they also showed better performance on tasks that targeted working memory (e.g., Blom, Küntay, Messer, Verhagen, & Leseman, 2014) and shifting (e.g., Prior & MacWhinney, 2010). This has interesting theoretical implications, especially when taken together with Miyake and Friedman’s (2012) revised theory of EF. As previously mentioned, the sub-system previously classified as *inhibition* has been found to overlap completely with the newly-proposed *common EF*. Additionally, this *common EF* appears to work together with the sub-systems of *working memory* and *shifting* whenever tasks targeted those sub-systems. This *common EF* could account for why bilinguals’ increased use of inhibition would lead to bilingual advantages in other areas of EF. More current research in bilingualism and EF takes a more domain-general approach to the bilingual advantage for this reason (e.g., Blom et al., 2014; Morales et al., 2013).

1.2.1.1. Inhibition in bilinguals and monolinguals

Bialystok, Martin, et al. (2005) used a Simon task in order to compare inhibition abilities in bilinguals and monolinguals at various ages. They found that bilingual five-year-olds were faster at responding to both congruent and incongruent trials on the Simon task. This faster RT for both trial types has been found in other studies of children (Martin-Rhee & Bialystok, 2008), although a few studies using the Simon task or other tasks of intrinsic inhibition have failed to find group differences in children (Morton & Harper, 2007; Goldman, Negen, & Sarnecka, 2014).

In addition to the Simon task, the flanker task has been used extensively to study inhibition differences between monolingual and bilingual children. Engel de Abreu, Cruz-Santos, Tourinho, Martin, and Bialystok (2012) compared monolingual and bilingual second-grade students in Luxembourg using a flanker task and found that while accuracy was at ceiling levels for both groups, the bilinguals were faster at responding to both congruent and incongruent trials. This finding, similar to the finding of faster overall RT in the Simon task, has been replicated in other studies of children (Kapa & Colombo, 2013). However, some studies have found that the bilingual advantage in the flanker task is specific to incongruent trials (Poarch & Bialystok, 2015; Yang et al., 2015). A minority of studies have found no bilingual/monolingual group differences on tasks of extrinsic inhibition (Carlson & Meltzoff, 2008; Ladas, Carroll, & Vivas, 2015). To summarize the bilingual advantage research with children, when bilingual children do outperform their monolingual peers, they tend to show global RT advantages, but when a task of extrinsic inhibition is used, the advantage can be found to be specific to incongruent conditions.

The bilingual advantage in tasks targeting inhibition has also been found in studies of adults. Young adults are often described as being at the peak of their cognitive abilities (Bialystok, Martin, et al., 2005), so bilingual advantages are typically only observed in studies with conditions of increased task difficulty (Bialystok, 2006; Bialystok & DePape, 2009; Costa, Hernández, & Sebastián-Gallés, 2008; Emmorey, Luk, Pyers, & Bialystok, 2009; Heidlmayr et al., 2014; Luk, De Sa, & Bialystok, 2011; Vega-Mendoza, West, Sorace, & Bak, 2015). When the task difficulty is not increased, group differences are generally not found (Bialystok, Craik, et al., 2005; Bialystok, Martin, et al., 2005; Luk, Anderson, Craik, Grady, & Bialystok, 2010). Studies with older adults often revert back to using the simpler versions of inhibition tasks used with children. Bialystok, Martin, et al. (2005) found that middle-age bilinguals (age range = 30-59 years) and older bilinguals (age range = 60-80 years) were faster on both congruent and incongruent trials of the Simon task compared to their monolingual peers. Other studies of older adults also find RT advantages for bilingual participants in this age group (Bialystok et al., 2008; Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006).

In their review of studies of bilingualism and inhibition, Hilchey and Klein (2011) argued that the prevalent findings of faster RT overall, and not just on incongruent trials, do not support even a more domain-general view of the bilingual advantage, since congruent trials in inhibition tasks require low EF involvement. They did, however, concede that the bilingual advantage for global RT is itself compelling and may be more illustrative of a general cognitive advantage, extending beyond EF. They proposed that the discrepant performance between monolinguals and bilinguals on these tasks may be indicative of a bilingual advantage in “conflict monitoring”. This framework proposes that rather than discrete performance changes between congruent and incongruent trials as we would expect based on the EF theories, the increased inhibition required to inhibit the interfering information on an incongruent trial can spill over onto subsequent trials, leading to improved performance even on congruent trials that follow. They point to studies such as Bialystok (2006) wherein bilinguals and monolinguals performed equivalently when the percentage of incongruent trials was low (37.5%), but bilinguals outperformed monolinguals when the percentage of incongruent trials was high (70%). Further research differentiating this framework from the domain-general EF theory is required.

1.2.1.2. Working memory in bilinguals and monolinguals

Studies looking at the effect of bilingualism on working memory typically ascribe the theoretical underpinning of bilingual advantages in working memory to more domain-general advantages in EF (Blom et al., 2014; Morales et al., 2013). This is reflected in the studies that have found bilingual advantages for tasks of working memory, but only in tasks with high EF demands (Blom et al., 2014). Morales et al. (2013) compared five- and seven-year old monolingual and bilingual children on a working memory task called the Frog Matrices Task

(FMT). In this computer-based task, the participant sees a 3×3 grid of squares, with each square representing a pond that may or may not contain a frog. The participant’s goal is to recall which ponds contain frogs. In the easier condition, a number of frogs appear in the squares *simultaneously*, and, after the frogs disappear, the participant touches the squares that contained frogs. In the harder condition, a number of frogs appear in the squares *sequentially*, and after the frogs disappear, the participant has to touch the squares that contained frogs but in the same order that they appeared. The results showed an interaction of task and language group where the bilinguals outperformed the monolinguals, but only on the harder condition. The harder condition required more conscious processing of the to-be-recalled information, and thus required more EF involvement. Therefore, this result can be considered to reflect a bilingual advantage even though the bilinguals only outperformed the monolinguals on one of the two tasks.

Calvo and Bialystok (2014) also used the FMT with monolingual and bilingual six-year-olds and found that the bilinguals performed better than the monolinguals on both tasks; however, their sample consisted of children from low- and middle-SES backgrounds. As previously discussed, low SES can have a negative impact on EF, perhaps making the simultaneous condition difficult enough for the bilingual advantage to surface in this sample.

Some studies have not found a working memory advantage for bilinguals compared to monolinguals. Engel de Abreu et al. (2012) found no differences between bilingual and monolingual children on each a task of working memory with low EF demands (i.e., information storage only) and with high EF demands (i.e., information storage and processing). Bonifacci, Giombini, Bellocchi, and Contento (2011) compared monolingual and bilingual children on verbal and non-verbal working memory tasks and found no group differences. Gutiérrez-Clellen, Calderón, and Weismer (2004) found that monolingual and bilingual children did not differ in their performance on a verbal working memory task. The lack of bilingual advantage in verbal working memory is to be expected. Even with a more efficient EF system, bilinguals still need to allocate some EF resources to language management during language-based tasks, leaving little room for advantages to emerge.

The findings in adults appear to be similar. Working memory tasks with low processing demands, such as simple span tasks, tend not to produce bilingual advantages (Bialystok et al., 2004; Ratiu & Azuma, 2014), whereas tasks with higher processing demands, such as a search task based on memorized stimuli, do produce bilingual advantages (Bogulski, Rakoczy, Goodman, & Bialystok, 2014). To summarize, it appears as though bilingual advantages in working memory do not extend to verbal working memory. They tend to appear in visuospatial working memory tasks when the task calls for not only storage of information, but also conscious processing.

1.2.1.3. Shifting in bilinguals and monolinguals

While some studies of children and adults have found no shifting advantages for bilinguals over monolinguals (Kaushanskaya, Gross, & Buac, 2014; Moradzadeh et al., 2015; Paap & Sawi, 2014), similar to the findings in working memory and inhibition, there is more evidence than not at this time to support a bilingual advantage in this domain. When investigating shifting abilities in children, the most commonly used task is the Dimensional Change Card Sort Task (DCCS; Zelazo, Frye, & Rapus, 1996). This task is similar to the previously described WCST, except that it is more appropriate for use with young children as the sorting rules are explicitly stated, and the cards can only be sorted along two dimensions. Using this task, advantages have been found for bilingual children over monolingual children

(Bialystok, 1999; Carlson & Meltzoff, 2008). Bialystok and Martin (2004) used the DCCS but slightly modified it in one condition so that the sorting dimensions were semantic (i.e., the pictured object's function versus the pictured object's typical location) rather than perceptual (i.e., the object's colour versus the object's shape). They found that the bilingual participants only had an advantage in the perceptual condition. This is consistent with the findings of no verbal working memory advantages for bilinguals. The semantic condition likely engages more language-based processing and would therefore split the bilinguals EF resources between language management and task completion.

Shifting abilities have been less studied in adults, but generally bilinguals have been found to outperform monolinguals on non-linguistic tasks that target shifting (Prior & MacWhinney, 2010; Wiseheart, Viswanathan, & Bialystok, 2016). Costa et al. (2008) found that bilingual participants were more efficient compared to monolingual participants at switching their response across trials of a Simon task. Furthermore, bilinguals had faster RT when the trials switched from incongruent to congruent. The authors concluded that bilingual participants demonstrated an advantage in shifting and domain-general EF processes that not only helped them to switch response sets more efficiently, but also helped them to resolve the conflict in trials of rapidly-switching congruence faster than monolinguals.

1.2.2. Factors that influence the bilingual advantage in EF

While the evidence reviewed above indicates that there is very likely some impact of bilingualism on EF abilities, there are other factors that interact with bilingualism which may account for why some studies do find advantages for bilinguals while others do not. There is no single way to be a bilingual. There are balanced bilinguals who have roughly equal proficiency in each of their languages, and there are dominant bilinguals who have greater proficiency in one language compared to the other. There are simultaneous bilinguals who were exposed to both of their languages within the first two years of life, and there are sequential bilinguals who learned a second language after establishing proficiency in their first language. There are even lapsed bilinguals who were previously bilingual but at some point lost proficiency in one of their languages. On the EF side, one must consider that other influences on EF development, such as SES and culture, are often confounded with bilingualism.

Many studies have considered the impact of language proficiency on EF abilities in bilinguals. Some studies find that a certain degree of bilingual proficiency is required for the bilingual advantage (Iluz-Cohen & Armon-Lotem, 2013; Tao, Marzecová, Taft, Asanowicz, & Wodniecka, 2011). For example, in a comparison of fluent bilinguals, lapsed bilinguals, and monolinguals, Bogulski et al. (2015) found that fluent bilinguals outperformed monolinguals on a task of working memory, and that the performance of the lapsed bilingual group fell between the two other groups. Likewise, Coderre, Van Heuven, and Conklin (2013) found that low-proficiency bilinguals experienced more interference relative to high-proficiency bilinguals. That said, the dominant view is that proficiency is not the best predictor of the bilingual advantages in EF. Heidlmayr et al. (2014) used multiple regression analysis to determine the factors that contribute to Stroop task performance and found no significant contribution of second-language proficiency. Rosselli, Ardila, Lalwani, and Vélez-Uribe (2015) compared balanced bilinguals, dominant bilinguals, and monolinguals, with participants with high and low language proficiency in each group. Proficiency was determined using a median split, with the high-scoring half of each language group making up the high proficiency groups. They found that language proficiency was not predictive of EF abilities, and that nonverbal intelligence was the best predictor.

One study found that degree of immersion or frequency of second-language use is a better predictor of EF advantages in bilinguals. Guerrero, Smith, and Luk (2015) interviewed the parents of Spanish-English bilingual preschoolers on their language usage at home and then tested the children on a flanker task. They found that chronological age and use of Spanish at home were better predictors of EF advantages than second language proficiency. The authors argue that during language development, second language proficiency as measured by norm-referenced assessments may not be the best indicator of bilingualism. Home language use, on the other hand, may be a better indicator of the degree to which the participants need to cognitively manage their two languages, and thus the degree to which they are likely to experience EF benefits.

Another related factor that has been found to contribute to EF advantages in bilinguals is whether the participants are simultaneous or sequential bilinguals. This area is still debated, as the literature is split between those finding that simultaneous bilinguals have a greater advantage on tasks of EF compared to sequential bilinguals (Kapa & Colombo, 2013; Luk et al., 2011; Struys, Mohades, Bosch, & van den Noort, 2015), and those finding no differences between the groups (Vega-Mendoza et al., 2015). Likewise, the question about whether sequential bilinguals still enjoy EF advantages relative to monolinguals has yet to be answered. Studies, in about equal numbers, find that sequential bilingual do have an EF advantage over monolinguals (Heidlmayr et al., 2014; Kaushanskaya et al., 2014; Nicolay & Poncelet, 2013; Vega-Mendoza et al., 2015), or do not (Kapa & Colombo, 2013; Luk et al., 2011; Tao et al., 2011).

A final factor that has been only briefly investigated in the literature is whether there are additional benefits for trilingual individuals compared to bilinguals on tasks of EF. Heidlmayr et al. (2014) found that frequency of use of a third language was negatively correlated with Stroop effect (i.e., trilingualism was associated with better performance). The authors argued that having to manage a third language does additionally influence the development of EF skills. In contrast, Poarch and Bialystok (2015) found that both bilingual and trilingual participants outperformed the monolingual and partially-bilingual participants on a flanker task, but found no difference between the bilingual and trilingual groups.

Other factors that may contribute to the bilingual advantage are more related to how the bilingual group is different from the monolingual group. As discussed earlier with regard to environmental factors affecting EF development, SES has been found to be a significant predictor of EF abilities in children (Sarsour et al., 2011). Some researchers argue that the effects of bilingualism and SES on EF are interactive (Calvo & Bialystok, 2014), while others argue that they are separable and non-interactive (Engel de Abreu et al., 2012). However, it should be noted that the direction of the relationship between bilingualism and SES is not always constant. Morton and Harper (2007) argued that the influence of SES is not sufficiently controlled in many studies finding bilingual advantages. They argue that studies based out of Canada are particularly confounded in terms of bilingualism and SES because the bilingual groups tend to be comprised of immigrants or children of immigrant parents. While the family income of immigrants is slightly lower than that of non-immigrants in Canada, due to immigration policy, immigrants are typically more highly educated compared to non-immigrants. After controlling for these variables using a very strict participant inclusion criteria, they found that the monolinguals and bilinguals performed the same on the Simon task.

Conversely, in studies outside of Canada, bilingualism is typically associated with lower SES. Blom et al. (2014) studied children in the Netherlands and reported that most of the bilingual Turkish immigrants in that country were of lower SES than non-immigrants. Comparing Turkish-Dutch bilingual children with Dutch monolingual children, they controlled for SES and found that the bilingual children had better performance on tasks of working memory. Similarly, Carlson and Meltzoff (2008) compared a group of low-SES bilingual children to a group of middle-SES monolingual children using EF tasks and found that without controlling for SES, the groups performed equivalently, but when controlling for SES, the bilingual group had better performance.

Likewise, culture has also been found to affect EF development and can be confounded in studies of bilingualism and EF. In most studies of bilingualism, the monolingual group tends to reflect the majority language and culture of the location of the study. The bilingual group, depending on whether the authors control for second language, may reflect either a single minority language and culture, or a group of participants from various minority languages and cultures. Bialystok and Viswanathan (2009) compared a group of monolingual English-speaking children from Canada to two bilingual groups: a group of bilingual children from Canada who spoke English and one of thirteen minority languages, and a group of bilingual children from India who spoke English and either Tamil or Telugu, none of which are minority languages. Where group differences were found between monolinguals and bilinguals, the two bilingual groups always performed equivalently, indicating that the differences between the groups was due to bilingualism and not culture or minority language status. Similarly, Yang et al. (2011) compared Korean-English bilinguals in the U.S.A. to three monolingual groups: Korean monolinguals in the U.S.A., English monolinguals in the U.S.A., and Korean monolinguals in Korea. They found that the difference between the bilingual group and monolingual groups were greater than the differences between the participants in the U.S.A. and the participants in Korea on flanker task performance. In contrast, Coderre et al. (2013) compared a group of English-speaking monolinguals from the UK to two groups of English-Chinese bilinguals: one group from the UK and one group from China. They found that only the bilinguals residing in China demonstrated a bilingual advantage on a Stroop task, indicating that the effect of culture might not always be outweighed by the effect of bilingualism. To summarize the findings of SES and culture, given that these variables are often confounded when comparing monolingual and bilingual groups, it is important that researchers implement proper controls in order to determine whether group differences are due to language status or SES and/or culture.

1.2.3. Bilingualism in clinical populations

Especially in North America, where single language exposure is seen as the norm, many teachers, pediatricians, and speech-language pathologists alike surmise that bilingualism would be an insurmountable challenge for children with developmental delays. This assumption is reflected by the pervasive “English-only” recommendation so often given to multilingual families of children with developmental delays. While this recommendation is likely based on the assumption of reduced language capacity in children with developmental delays and the practical need of the child to acquire the majority language of their culture, it is not supported by the clinical research. It is also not in accordance with the recommendations of both the American Speech-Language-Hearing Association (2017a) and Speech-Language and Audiology Canada (SAC; Crago & Westernoff, 1997), both of which recommend assessing and treating in both languages, if possible, or at least considering the family's cultural and linguistic preferences when selecting a language of intervention.

There is evidence from research on children with Down syndrome (DS) and specific language impairment (SLI) to support the notion that bilingualism is not too difficult for children with developmental disorders. Studies of children with DS have revealed two important findings: first, there are no differences on measures of first language acquisition when comparing those who are exposed to a single language to those who are exposed to two languages, and second, that children with DS who are exposed to a second language are able to acquire receptive and expressive skills in their second language (Feltmate & Kay-Raining Bird, 2008; Kay-Raining Bird et al. 2005). Similarly, the small body of research looking at children with SLI indicates that bilingualism does not place an undue burden the child's language acquisition (Korkman et al., 2012; Paradis, Crago, Genesee, & Rice, 2003).

1.2.3.1. Advice given to families of children with ASD

Several ethnographic studies have investigated the advice that has been given to parents of children with developmental delays regarding bilingual language exposure and whether their child might succeed in dual language acquisition. Based on these reports, parents are repeatedly being advised to cease use of their home language and to adopt an "English-only" (EO) approach to speaking with their child (Fernandez y Garcia, Breslau, Hansen, & Miller, 2012; Jegatheessan, 2012; Kremer-Sadlik, 2005; Yu, 2013). Jegatheessan (2012) reported on a family who had the experience of their child's teachers and therapists trying to "catch" them using their home language by secretly questioning extended family members about language use in the child’s home. This family reported that it became easier to tell those working with their child that they were following the EO recommendation, even if this was not the truth.

Adhering to the EO recommendation ranges from difficult to impossible, depending on the role of the home language in the family. While some families do adopt the EO approach, other families do not for reasons ranging from lack of proficiency in English (Yu, 2013) to maintain religious traditions (Jegatheessan, 2012). In addition to the impact on the family, these recommendations can have a negative impact on the children themselves as they can become isolated from their families and cultural community (Kremer-Sadlik, 2005). Finally, looking into the heart of this problem, previous research has shown that parents are the primary language models for children with ASD (Baron-Cohen & Staunton, 1994). When parents are not proficient in the language they are modelling for the child, this leads to an ungrammatical and unexpanded language model for a child who may already have delayed language development. Hambly and Fombonne (2012) found that sequentially bilingual children with ASD performed worse than the monolinguals and simultaneous bilinguals on measures of social skill development. The authors surmised that in the case of the sequential bilinguals, the families added a majority language once they began having concerns about their child’s development, as therapy often uses the majority language, and decreased the use of the minority home language. The EO recommendation, given with the good intention of improving the child’s proficiency in the majority language, may not even have that effect.

1.2.3.2. Bilingualism in children with ASD

Very little research has investigated the impact of bilingual language exposure on the development of children with ASD. This small research base has been restricted to questions of language acquisition. One important finding of this research is that bilingualism is an achievable outcome for children with ASD. Hambly and Fombonne (2014), in a study of three- to seven-year-olds with ASD, found that bilingualism was present across the range of cognitive abilities in their sample, including those with moderate-severe cognitive impairments. Petersen, Marinova-Todd, and Mirenda (2012) explored the impact of Chinese-English bilingual language acquisition on the expressive and receptive vocabulary development of children (mean age = 59 months) with ASD. Previous research with TD children has demonstrated that while a bilingual child may have a smaller vocabulary in each of their languages when compared to a monolingual who speaks that language (Bialystok, Luk, Peets, & Yang, 2015), they tend to have equal or greater vocabularies compared to monolinguals when lexical items are counted across languages (i.e., conceptual vocabulary). The results revealed that the bilingual group not only had the hypothesized equivalent receptive conceptual vocabulary, but in fact had a significantly larger productive conceptual vocabulary when compared to their monolingual peers. These results once again indicate that children with ASD are able to acquire two languages, and that bilingual lexical acquisition occurs in a similar pattern in children with ASD as in TD children.

Another important finding from the bilingualism and ASD research is that bilingual language exposure does not appear to cause any additional delays in the child's first language. Ohashi et al. (2012) compared preschool aged children with ASD with either bilingual language exposure or monolingual language exposure on a number of indices of early communication. The participants were each tested in their dominant language. The measures targeted ASD-related communication impairment, age of first words, age of first phrases, receptive language scores, expressive language scores, and functional communication scores.

The authors found no differences between the children with single or dual language exposure on any of these indices of early communication, suggesting that the presence of a second language in the child's environment did not hinder the development of early language skills in their dominant language. These results are echoed by Reetzke, Zou, Sheng, and Katsos (2015) who found no differences on measures of linguistic development or social skills when comparing a group of children with ASD who were either exposed to one or two Chinese languages.

A third important finding from this literature is the possibility that dual language exposure may positively affect cognitive and linguistic development in children with ASD; however, the extent to which this happens and the cognitive processes affected have yet to be determined. To date, no research has investigated the impact of bilingual language exposure on EF development in children with ASD. Valicenti-McDermott et al. (2012) conducted a retrospective comparison of children exposed to only one language and children exposed to two languages on a number of measures at the time of their ASD diagnosis. They found the bilingual group had higher scores on the Vineland Adaptive Behaviour Scales, with specific differences in the expressive language domain, wherein the bilingual exposure group used more pointing, leading an adult to a desired object, and cooing compared to the monolingual exposure group. These results suggest that bilingual language exposure does not hinder and may actually support the early communicative development of children with ASD. A similar finding was reported by Hambly and Fombonne (2012) who found that in a group of three- to six-year-olds with ASD, children who had been exposed to two languages since birth had higher scores on the portions of the Vineland Adaptive Behaviour Scales-II that targeted social skill development compared to the children with monolingual language exposure.

1.3. Current study

The current thesis aimed to answer the following question: Is there a bilingual advantage on tasks of EF in children with ASD? In addition to the theoretical importance of this population for the bilingualism research, there is further practical and clinical importance to this research. ASD now affects one in every 68 children, with a trend toward increasing prevalence (Autism Speaks Canada, 2015). At the same time, the rate of bilingualism and multilingualism in Canada rose from 14.2% to 17.5% of the population between 2006 and 2011, largely due to immigration (Statistics Canada, 2014). More specific to the participant population of this study, the Canadian census found that in Vancouver, BC, the number of families reporting that they speak English and an ‘other’ language in equal proportions rose from 19.7% in 2006 to 24.0% in 2011 (Statistics Canada, 2014). With both the prevalence of ASD and the rate of bilingualism growing, one can safely conjecture that the number of bilingually-exposed children with ASD is likewise increasing.

Additionally, there is still the propagation of the folk-wisdom that bilingualism is too difficult for children with ASD among child developmental specialists as well as parents and caregivers. Therefore, research into the effects of bilingualism on this population would further inform the evidence-based practice of health care and educational professionals working with clients with ASD and their families, such as speech-language pathologists, pediatricians, and special educators.

Based on the robust findings of bilingual advantages in EF in TD children, the finding that bilingual language exposure does not interfere with the language development in children with ASD, and the finding that environmental supports for EF development are most effective in individuals with the most to gain, this study had the following hypotheses:

1. Bilingual children with ASD were expected to perform better than their monolingual peers with ASD on two tasks of inhibition: the Simon task and the flanker task. Better performance on these tasks was expected to be reflected in global accuracy and/or RT advantages, or accuracy and/or RT advantages specific to incongruent conditions.
2. Bilingual children with ASD were expected to perform better than their monolingual peers with ASD on two tasks of visuospatial working memory: a forward-span task and a backward-span task.

This study also aimed to address the following secondary question: Does participation in activities such as playing video games, taking music lessons, and participating in regular exercise lead to improved performance on tasks of EF in children with ASD? The following hypotheses were tested:

3. Children who participate in EF-supporting activities such as playing video games, taking music lessons, and participating in regular exercise were expected to perform better than their peers who do not participant in these activities on two tasks of inhibition: the Simon task and the flanker task. Better performance on these tasks was expected to be reflected in global accuracy and/or RT advantages, or accuracy and/or RT advantages specific to incongruent conditions.
4. Children who participate in EF-supporting activities such as playing video games, taking music lessons, and participating in regular exercise were expected to perform better than their peers who do not participant in these activities on two tasks of visuospatial working memory: a forward-span task and a backward-span task.

2. Methods

2.1. Data collection protocol

Data were collected during a two-hour assessment session that took place in each participant's home. First, the experimenter explained the study to and secured consent from the participant's parent/guardian. Next, the parent/guardian was given a language history questionnaire for completion during the first portion of data collection. The experimenter then obtained verbal assent from the participant and completed assessments of receptive vocabulary and nonverbal intelligence. After these assessments, the participant was given a break while the experimenter reviewed the language history questionnaire and conducted a semi-structured interview with the parents. Finally, after their break, the participant completed four EF tasks. The Simon task and flanker task were completed first, and the order of these two tasks was counterbalanced. The working memory tasks followed, and the order of these two tasks was likewise counterbalanced. At the end of the testing session, the participant was given a small educational toy or book as a token of gratitude.

2.2. Participants

The participants for this study were recruited based on the following inclusion criteria: (a) the child must have a formal diagnosis of autism spectrum disorder, (b) be between six and ten years of age, and (c) be exposed to only English or English plus another language on a regular basis. Participants were excluded from participation if they had a diagnosed intellectual disability, a genetic or chromosomal anomaly, or a significant and/or uncorrected vision or hearing impairment.

Recruitment took place primarily via word-of-mouth between parents of children with ASD and through e-mails to parents from various local ASD and developmental disability organizations. Several local speech-language pathologists and occupational therapists also helped with participant recruitment.

In total, twelve children participated in this study. Of these children, there were ten male and two female participants. The chronological ages of the participants ranged from 76 to 131 months (mean = 100.25 months). Ten participants had a formal diagnosis of ASD while two had received diagnoses of Pervasive Developmental Disorder – Not Otherwise Specified. All participants received their ASD diagnosis while living in Canada. Five participants received their ASD diagnoses through the BC Autism Assessment Network. Seven participants received their ASD diagnoses through private assessments. Both paths to ASD diagnosis are required to follow the Standards and Guidelines for the Assessment and Diagnosis of Young Children With Autism Spectrum Disorder in British Columbia (Dua, 2003), assuring the validity of diagnosis between public and private options.

Eight of twelve participants completed all tasks, whereas four did not complete one or more task: (a) participant 1 did not complete the backward-span working memory task or the flanker task; (b) participant 4 did not complete the forward-span working memory task; (c) participant 7 did not complete the KBIT, either working memory tasks, the Simon task or the flanker task; and (d) participant 8 did not complete the backward-span working memory task. Data from participants 1 and 7 were not used in any analyses as they did not complete both inhibition tasks. From this point on, data are reported only for ten participants.

Participants were assigned to either the monolingual group or the bilingual group based on their exposure to a second language. This was determined using the language history questionnaire and semi-structured caregiver interview. Participants with 30-50% exposure to a language other than English for at least two years prior to the study were assigned to the bilingual group. Language exposure in all environments was considered equal, allowing for the inclusion of children in French Immersion or other school-based language programs. Participants with less than 10% total exposure to a language other than English were placed in the monolingual group. Potential participants who fell in between these values were not retained for the study. There was no proficiency requirement for either group.

Determining monolingual and bilingual group status based on language exposure is thought to be sufficient for two reasons. First, the inhibitory mechanisms at work during language management have been found to be active during tasks of auditory comprehension as well as verbal expression (Marian & Spivey, 2003; Spivey & Marian, 1999). Therefore, even if a child has not achieved productive proficiency in a second language, he/she should still be accruing the EF benefits of bilingualism with bilingual exposure. Second, previous research has found that proficiency is not the best predictor of EF advantages in children, and that current exposure and use of a second language are better predictors of EF advantages (Guerrero et al., 2015).

2.2.1. Description of bilingual group

Six participants (all male) comprised the bilingual group. The language acquisition histories of these participants were very diverse. Two participants were classified as simultaneous bilinguals, as they began acquiring both of their languages before the age of two and continued to be exposed to both languages until the time of testing. Four participants were classified as sequential bilinguals, as they began acquiring a second language after the age of three and continued to be exposed to both languages until the time of testing. Of these four sequential bilinguals, two were optional language learners, as they began acquiring an additional language through an optional school-based program (i.e., French Immersion) rather than through home- or cultural exposure. These two participants spoke primarily English at home and in the community and French at school. The remaining two participants primarily used a minority language in the home, and English in the community and at school. The languages other than English represented include French (2), Mandarin (1), Spanish (1), Hindi (1), and Urdu (1).

As part of the language history questionnaire, one caregiver for each participant was asked to rate the participant's language proficiency on a scale of one to seven, corresponding to the following descriptors: 1 – *very poor*; 2 – *poor*; 3 – *fair*; 4 – *functional*; 5 – *good*; 6 – *very good*; 7 – *native-like*. Ratings were requested for listening, speaking, reading, and writing for each language spoken by the participant. Parents were asked, to the best of their ability, to rate their child's proficiency relative to their age. Table 2.1 shows the language proficiency ratings for the bilingual group participants, by parent report.

Table 2.1 Caregiver ratings (from 1 – very poor to 7 – native-like) of bilingual participants' language proficiency.

Part.	L1	AoE	L	S	R	W	L2	AoE	L	S	R	W
Simultaneous bilingual participants												
6	Spanish	Birth	6	4	2	2	English	2	5	5	6	5
8	English	Birth	2	5	2	2	Hindi	Birth	2	3	-	-
Sequential bilingual participants												
Part.	**L1**	**AoE**	**L**	**S**	**R**	**W**	**L2**	**AoE**	**L**	**S**	**R**	**W**
2	Mandarin	Birth	2	2	2	2	English	3	3	2	2	3
4	English	Birth	7	7	7	6	French	6	7	7	7	6
10	English	Birth	4	4	4	2	French	5	4	4	2	2
11	Urdu	Birth	5	3	-	-	English	4	7	7	4	4

Part. = participant, L1 = first language, L2 = second language, AoE = age of exposure (in years), L = listening, S = speaking, R = reading, W= writing.

Participants' mean age was 103.67 months (range: 79-128 months). All but one participant was born in Canada, but the participant born outside of Canada had resided in Canada for over six years. All participants attended school full time, with the following special circumstances: one participant attended a Montessori school, one participant received special education support, and two participants attended French Immersion programs. Two participants had additional diagnoses: one was diagnosed with a language impairment, and one had diagnoses of both ADHD and anxiety.

Information about the participants' parents' education and employment was also collected. All parents had completed at least some college or university coursework, with most of the parents having completed an undergraduate or Masters level degree. Many of the mothers were stay-at-home caregivers for their families. Parents who worked outside of the home were employed in a variety of industries including healthcare, education, business, and hospitality.

Finally, information was gathered on parents' rating of their own proficiency in each language they use. Proficiency was rated on the same one to seven scale described above. All parents rated their proficiency in their primary language as *native-like* across all language skills. Second language skills varied greatly among participant's parents, but the average rating for each language skill was at least *functional*.

2.2.2. Description of monolingual group

Four participants (two males and two females) comprised the monolingual group. All participants used English in their daily communication in the home, school, and community. One participant had previously been enrolled in a French Immersion program for one year, but left the program approximately one year prior to this study due to lack of progress in acquiring French. This participant's parent did not believe the child had any functional use of French, nor had he been exposed to French since leaving the program.

The mean age of children in this group was 107 months (range: 76-131 months). All but one participant were born in Canada, but the participant born outside of Canada had resided in Canada for over four years. All participants attended school full time, with one participant receiving special education support. Two participants had additional diagnoses:

one was diagnosed with a pragmatic language impairment, and one was diagnosed with a learning disability.

Information about the participants' parents' education and employment was also collected. All parents had completed at least some college or university coursework, with most of the parents having had completed undergraduate or Doctorate level degrees. All parents worked outside of the home are employed in a variety of industries including healthcare, business, and performing arts.

Finally, information was gathered on parents' rating of their own proficiency in each language they use. Proficiency was rated on the same one to seven scale described in the previous section. Most parents were monolingual and reported all language skills to be *native-like*. A few parents had some proficiency in other languages, but typically rated these language skills as below *functional*.

2.2.3. Activity groups

Participant data were also analysed based on their participation in select activities which have been found to enhance EF abilities in children and adults: playing video games, playing a musical instrument, and engaging in regular exercise. Participants' membership in each activity group was based on parent report. If participants currently engaged in an activity for at least one hour per week, they were assigned to that activity group. Parents were also asked to report on the nature of their child's activity involvement (i.e., type of video games; specific musical instrument; sport). Exercise during school hours as a part of recess or regular physical education was not included in estimates of the participants' regular exercise, as this was assumed to be relatively equal across participants.

2.3. Materials

2.3.1. Matching measures

In order to ensure that the bilingual and monolingual groups were comparable, all participants were assessed on two measures. The Peabody Picture Vocabulary Test - 4th edition (PPVT; Dunn & Dunn, 2007) was used to assess English receptive vocabulary. The Matrices subtest of the Kaufman Brief Intelligence Test, 2nd edition (KBIT; Kaufman & Kaufman, 2004) was used to assess nonverbal intelligence.

In order to gather more information about the participants' socioeconomic background and language proficiency in each of their languages, one parent/guardian for each participant was asked to complete a language history questionnaire (see Appendix). This questionnaire, adapted by the author from similar questionnaires in prior studies, targeted the following areas: previous places of residence, presence of visual/hearing impairment, other diagnoses in addition to ASD, participant's education, therapy and intervention history, education and employment of the participant's primary caregivers, languages spoken in the home, self-reported language proficiency of the primary caregivers, and caregiver rating of the participant's language proficiency.

After review of the questionnaire, a semi-structured caregiver interview was conducted by the experimenter. This interview targeted the following: participant's language exposure in infancy, changes that were made to the participant's language exposure around the time of ASD diagnosis, periods of time when the participant experienced changes to their typical language exposure, language use/exposure associated with specific people, and language use/exposure associated with specific locations.

2.3.2. Simon task

The Simon task is computer-based, and was programmed by the author using E-Prime 2.0 software (Psychology Software Tools, 2012). During this task, the child sat in front of a laptop computer, with his/her left index finger over a key with a blue sticker on it and his/her right index finger over a key with a red sticker. A cardboard cover was placed over the rest of the keyboard to prevent the child from accidentally ending the task or pressing the wrong key. The objective of this task is to press the left-hand blue key when a blue square appears on the screen and the right-hand red key when the red square appears on the screen. Half of the blue squares appeared on the left-most side of the screen (i.e., congruent condition), and half appeared on the right-most side of the screen (i.e., incongruent condition). The same split occurred for the red squares as well.

Audio-recorded instructions were played for the child prior to beginning the task. The child was instructed on the colour rule, and was encouraged to respond as accurately and as quickly as possible. Following the instructions, the child completed an eight-trial block of practice trials. Each trial was preceded by a 500ms fixation cue (i.e., +) in the center of the screen. The coloured square stimulus was presented until the child responded or for a maximum of 5000ms. Feedback was provided after each trial during the practice block. If the participant responded accurately, a picture of a star and a brief sound clip were played. If the participant made an error, he/she was reminded of the colour rule. If the 5000ms elapsed with no response, the participant was reminded to respond as quickly as possible. If a participant made more than two errors during the practice block, he/she repeated the practice trials.

Once the practice trials were complete, participants did not receive corrective feedback during the testing phase. However, in order to maintain participant engagement, after every eighth trial, a child-friendly picture and an associated sound (i.e., a picture of a dog with barking and panting sounds) were presented until the child pressed a button indicating that he/she was ready to continue. In total, each participant completed forty trials of the Simon task (twenty congruent and twenty incongruent). Accuracy and RT were measured for each trial. Only non-practice trials were analysed.

2.3.3. Flanker task

The task is computer-based, and was programmed by the author using E-Prime 2.0 software (Psychology Software Tools, 2012). During this task, the child again sat in front of a laptop computer, with his/her left index finger over a key on the left side of the keyboard and his/her right index finger over a key on the right side of the keyboard. A cardboard cover was placed over the rest of the keyboard to prevent the child from accidentally ending the task or pressing the wrong key. The objective of this task is to press the left-hand key when the central fish stimulus was facing to the left and the right-hand key when the central fish stimulus was facing to the right. The central fish stimuli was identical to the flanker fish. The central fish was flanked by two fish on either side. In one third of the trials, the flanker fish faced the same direction as the central fish (i.e., congruent condition); in another third, the flanker fish faced the opposite direction as the central fish (i.e., incongruent condition); and in a final third, the flanker fish were replaced by similarly sized ovals (i.e., neutral condition). Initially, the neutral flankers contained an ‘X’ in order to match the level of visual information in the fish flanker conditions; however, one participant interpreted the ‘X’ stimulus as a cue to not respond. This participant’s data was not used in analysis of the flanker task, and the task was subsequently modified to the version described above (i.e., no ‘X’ in the oval).

Audio-recorded instructions were played for the child prior to beginning the task. The child was instructed on how to respond to the fish facing each direction, and was encouraged to respond as accurately and as quickly as possible. Following the instructions, the child completed a twelve-trial block of practice trials. Each trial was preceded by a 500ms fixation cue (i.e., +) in the center of the screen. The fish stimulus was then presented until the child responded or for a maximum of 5000ms. Feedback was provided after each trial during the practice block. If the participant responded accurately, a picture of a smiling sun and a brief sound clip were played. If the participant made an error, he/she was reminded of the directional rule. If the 5000ms elapsed with no response, he/she was reminded to respond as quickly as possible. If a participant made more than two errors during the practice block, he/she repeated the practice trials.

Once the practice trials were complete, the participants did not receive corrective feedback during the testing phase. However, in order to maintain participant engagement, after every sixth trial, a child-friendly picture and an associated sound were presented until the child pressed a button indicating that he/she was ready to continue. In total, each participant completed sixty trials of the flanker task (twenty congruent, twenty incongruent, and twenty neutral). Accuracy and RT were measured for each trial. Only non-practice trials were analysed.

2.3.4. Forward-span working memory task

The task is computer-based, and was programmed by the author using E-Prime 2.0 software (Psychology Software Tools, 2012). During this task, the child was required to watch a sequence of lit-up squares in a 3×3 grid on the screen and recreate this sequence on the computer keyboard’s number pad. A different cover than the one used for the Simon and flanker tasks was placed over the rest of the keyboard. The number pad keys were covered with white stickers so that they resembled the 3×3 grid on the screen. The task only took up the right-half of the computer screen in order to increase the association between the 3×3grid on the screen and the number pad response keys.

Audio-recorded instructions were played for the child prior to beginning the task. The child was instructed to watch the 3×3 grid on the screen as the squares in the grid would light up in a sequence. Each square in the sequence would light up for 1000ms, with 200ms between each square. After the sequence was presented, the child was prompted to reproduce the sequence in the same order on the number pad keys on the laptop. After the sequence had been produced on the keys, the experimenter pressed *Enter* to trigger the next sequence. Response speed was not emphasized during this task, only accuracy.

Following the instructions, the participant completed a six-trial practice block. The number of squares in each sequence began at two and, after three trials, increased to three. During the practice block, feedback was provided. If the participant responded accurately, a picture of a rainbow and a brief sound clip were played. If the participant made an error, he/she was reminded to watch the sequence carefully. If the participant did not respond, the experimenter verbally reminded him/her of the instructions. After the practice block, the participant did not receive corrective feedback, and the sequence span restarted at two. If the participant was accurate on two out of three trials at this span, the number of lit-up squares in the sequence increased by one. This continued until the participant made errors on two or more trials out of three up to a maximum span of six. In order to maintain participant engagement, after every three trials, before the difficulty increased, a child-friendly picture and an associated sound were presented until the child pressed a button indicating that he/she was ready to continue.

Participants received two scores for this task. First, the maximum span at which the participant was accurate on two out of three trials was considered their *span*. The maximum span was six. Second, each trial was analyzed for the participant's *score* on this task. Each response within a trial could garner the participant a maximum of two points: one for presence and one for order. Figure 2.1 illustrates the scoring of a three-span trial. With the span ranging from two to six, and three trials at each span length, the maximum score was 120.

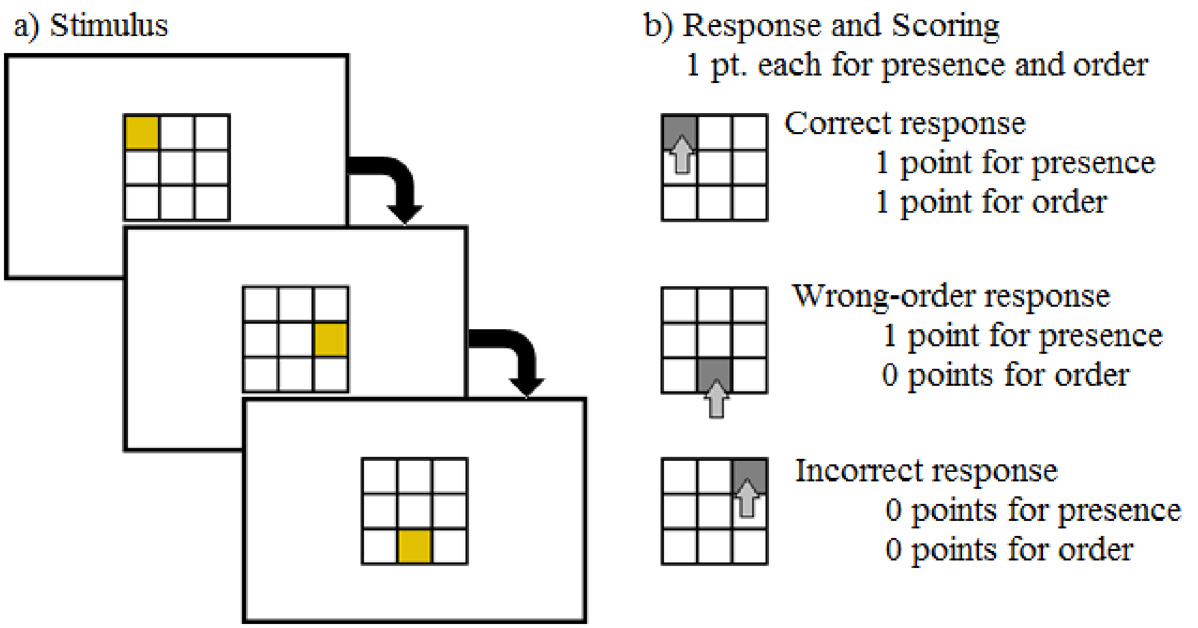

Figure 2.1 Illustration of working memory task scoring.

2.3.5. Backward-span working memory task

The task is computer-based, and was programmed by the author using E-Prime 2.0 software (Psychology Software Tools, 2012). It is mostly identical to the forward-span working memory task except that, after watching the sequence of squares on the screen, a participant must respond by reproducing the sequence in a backward order on the number pad. The procedure for advancing the difficulty of the trials and the measurement of *span* and *score* were identical to the forward-span task.

2.4. Data refinement procedure

2.4.1. Simon task

In total, testing produced data from 400 trials on the Simon task. All participants achieved accuracy above chance. There were no trials that ‘timed-out’ (i.e., ended after 5000ms had elapsed). Trials with response times faster than 150ms and slower than 2.5 SD above the mean for this task (1670 ms) were removed. This resulted in the removal of eight trials (2.0%). After data refinement, there were 392 trials remaining for accuracy analysis. Trials with inaccurate responses were not included in RT analysis. This resulted in 353 trials for RT analysis.

2.4.1.1. Flanker task

In total, testing produced data from 600 trials on the flanker task. All participants achieved accuracy above chance. Trials that ‘timed-out’ were removed from the data. Based on experimenter observation, this only occurred when a participant was distracted, such as when a parent spoke to them. This resulted in the removal of three trials (0.5%). Trials with reaction times faster than 150ms and slower than 2.5 SD above the mean for this task (1763 ms) were removed. This resulted in the removal of twenty-one trials (3.5%). After data refinement, there were 576 trials remaining for accuracy analysis. Trials with inaccurate responses were not included in RT analysis. This resulted in 544 trials for RT analysis.

3. Results

Data was analyzed from a total of ten participants. The mean standard score on the PPVT was 99.20, and the mean standard score on the KBIT was 107.90. Due to the small sample size in this study, tests of normality could not be reliably interpreted. Therefore, non-parametric methods were used throughout the analysis.

3.1. Comparison of monolingual and bilingual groups

Table 3.1 shows the results for the bilingual and monolingual group comparison on the matching measures as well as chronological age. The monolingual group had a greater mean PPVT score compared to the bilingual group; however, this is a common finding in research comparing monolingual and bilingual groups (Bialystok et al., 2010). The monolingual group also had a slightly greater mean KBIT score and was older compared to the bilingual group. However, all cases the group ranges were overlapping. None of differences achieved statistical significance, and therefore, for the remaining analyses, the bilingual and monolingual groups were judged to be equivalent in terms of receptive language, non-verbal intelligence, and age.

Table 3.1 Comparison of bilingual and monolingual participants on chronological age and matching measures.

	Bilinguals **n = 6**	**Monolinguals** **n = 4**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Age (months)	103.67 (79-128)	107 (76-131)	12.0	1.00
PPVT – Standard Score	96.50 (81-127)	103.25 (80-123)	10.0	.670
KBIT – Standard Score	107.17 (89-134)	109 (86-139)	11.0	.831

3.2. Comparison of activity groups

Table 3.2 shows background assessment results for each of the groups of participants who do or do not play video games, attend music lessons, and/or participate in regular exercise. No group differences were found on background measures.

Table 3.2 Comparison of activity groups on background measures and age.

	VG **n = 7**	**Non-VG** **n = 3**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Age (months)	110.29 (76-131)	92.67 (79-119)	7.0	.425
PPVT – Standard Score	104.57 (80-127)	86.67 (81-92)	3.0	.087
KBIT – Standard Score	108.57 (86-134)	106.33 (89-126)	10.0	.909
	Music **n = 4**	**Non-Music** **n = 6**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Age (months)	117.50 (111-128)	96.67 (76-131)	4.0	.088
PPVT – Standard Score	99.50 (81-127)	99.00 (80-123)	11.0	.831
KBIT – Standard Score	105.75 (90-134)	109.33 (86-139)	11.5	.915
	Exercise **n = 7**	**Non-Exercise** **n = 3**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Age (months)	108.14 (76-131)	97.67 (79-110)	5.0	.210
PPVT – Standard Score	99.00 (80-127)	99.67 (87-114)	9.0	.732
KBIT – Standard Score	110.57 (86-139)	101.67 (89-121)	7.5	.493

VG = video games.

3.3. Simon task results

Table 3.3 shows the accuracy and RT results for all participants. Wilcoxon signed rank tests showed that participants were significantly more accurate on congruent trials (*M* = 96%) compared to incongruent trials (*M* = 84%), *Z* = -2.199, *p* < .05., and that participants had significantly faster RT on congruent trials (*M* = 778.75 ms) compared to incongruent trials (*M* = 865.10 ms), *Z* = -2.701, *p* < .05.

Table 3.3 Simon task accuracy and RT data for all participants.

	All trials	**Congruent trials**	**Incongruent trials**	**Trial type comparison**	
Measure	Mean (range)	Mean (range)	Mean (range)	*Z*-value	*p*-value
Accuracy (%)	90 (71-98)	96 (90-100)	84 (50-100)	-2.199	**.028**
RT (ms)	816.94 (712-1026)	778.75 (639-990)	865.10 (740-1097)	-2.701	**.007**

RT = response time.

3.3.1. Group comparisons

Table 3.4 shows the results for the bilingual and monolingual group comparison on the Simon task. The monolingual group (*M* = 100%) had significantly higher accuracy than the bilingual group (*M* = 94%) on congruent trials, *U* = 0.0, *p* < .05. No further group differences were identified in Simon task performance.

Table 3.4 Comparison of monolingual and bilingual groups on the Simon task.

	Bilingual **n = 6**	**Monolingual** **n = 4**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Total accuracy (%)	89 (71-98)	91.5 (88-97)	11.5	.915
Congruent accuracy (%)	94 (90-95)	100 (--)	0.0	**.006**
Incongruent accuracy (%)	84 (50-100)	83 (75-94)	8.5	.453
Overall RT (ms)	810.22 (712-1026)	827.02 (727-915)	9.0	.522
Congruent RT (ms)	779.87 (655-990)	777.07 (639-884)	11.0	.831
Incongruent RT (ms)	848.65 (740-1097)	889.77 (825-953)	8.0	.394
SE on RT (ms)	68.78 (-1-132)	112.70 (65-206)	9.0	.522

RT = response time, SE = Simon effect.

Table 3.5 shows the results of activity group comparisons on Simon task performance. Mann-Whitney *U*-tests revealed that participants who engaged in regular exercise had significantly higher overall accuracy, $U = 1.0$, $p < .05$, and significantly higher incongruent trials accuracy, $U = 1.5$, $p < .05$, compared to those who did not. No other group differences were identified.

Table 3.5 Comparison of activity groups on the Simon task.

	VG	**Non-VG**		
	n = 7	**n = 3**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Total accuracy (%)	90 (85-97)	89 (71-98)	7.0	.422
Congruent accuracy (%)	97 (90-100)	93 (90-95)	4.5	.143
Incongruent accuracy (%)	84 (75-95)	83 (50-100)	7.0	.422
Overall RT (ms)	813.46 (721-915)	825.04 (712-1026)	9.0	.732
Congruent RT (ms)	769.66 (639-884)	799.96 (675-990)	10.0	.909
Incongruent RT (ms)	866.14 (758-959)	862.65 (740-1097)	7.0	.425
SE on RT (ms)	96.49 (-1-206)	62.69 (6-108)	8.0	.569
	Music	**Non-Music**		
	n = 4	**n = 6**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Total accuracy (%)	93 (90-98)	88 (71-98)	6.5	.238
Congruent accuracy (%)	95 (90-100)	97 (90-100)	9.0	.494
Incongruent accuracy (%)	91 (84-100)	79 (50-100)	5.5	.163
Overall RT (ms)	772.84 (721-875)	846.33 (712-1026)	8.0	.394
Congruent RT (ms)	743.44 (655-825)	802.29 (639-990)	8.0	.394
Incongruent RT (ms)	805.27 (740-936)	904.98 (750-1097)	5.0	.136
SE on RT (ms)	61.83 (-1-132)	102.69 (65-206)	10.0	.670

	<u>Exercise</u> **n = 7**	**<u>Non-Exercise</u>** **n = 3**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Total accuracy (%)	94 (88-98)	82 (71-89)	1.0	**.029**
Congruent accuracy (%)	96 (90-100)	95 (90-100)	8.5	.626
Incongruent accuracy (%)	90 (75-100)	68 (50-80)	1.5	**.039**
Overall RT (ms)	777.94 (712-915)	907.93 (791-1026)	3.0	.087
Congruent RT (ms)	738.73 (639-884)	872.13 (761-990)	3.0	.087
Incongruent RT (ms)	824.17 (740-953)	960.59 (825-1097)	3.0	.087
SE on RT (ms)	85.44 (-1-206)	88.46 (65-108)	10.0	.909

VG = video games, RT = response time, SE = Simon effect.

3.4. Flanker task results

Table 3.6 shows the accuracy and RT results for all participants who completed the flanker task. A Friedman test revealed that congruence did not result in any significant differences in either accuracy ($\chi2$ = 1.5, *df* = 2, *n.s.*) or RT ($\chi2$ = 0.2, *df* = 2, *n.s.*). Given that neutral trials were not found to be different from either congruent or incongruent trials, they were not analyzed further.

Table 3.6 Flanker task accuracy and RT data for all participants.

	All trials	**Congruent trials**	**Neutral trials**	**Incongruent trials**	**Trial type comparison**	
Measure	Mean (range)	Mean (range)	Mean (range)	Mean (range)	$\chi 2$	*p*
Accuracy (%)	94 (88-100)	94 (83-100)	94 (85-100)	95 (84-100)	1.5	.472
RT (ms)	727.14 (536-939)	722.84 (502-964)	740.11 (563-993)	744.00 (520-932)	0.2	.905

RT = response time.

3.4.1. Group comparisons

Table 3.7 shows the comparison of the bilingual and monolingual groups on flanker task performance. The bilingual group (*M* = 98%) had significantly higher accuracy than the monolingual group (*M* = 88%) on congruent trials, *U* = 1.0, *p* < .05. No further language exposure group differences were found in the flanker task.

Table 3.7 Comparison of monolingual and bilingual groups on the flanker task.

	Bilingual **n = 6**	**Monolingual** **n = 4**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Total accuracy (%)	97 (90-100)	91 (88-98)	4.0	.084
Congruent accuracy (%)	98 (95-100)	88 (83-95)	1.0	**.014**
Incongruent accuracy (%)	96 (89-100)	95 (85-100)	9.5	.567
Overall RT (ms)	738.62 (536-939)	709.93 (550-774)	11.0	.831
Congruent RT (ms)	744.43 (502-964)	690.46 (543-786)	10.5	.748
Incongruent RT (ms)	752.92 (544-932)	730.64 (520-863)	11.0	.831
FE on RT (ms)	30.53 (-72-85)	40.18 (-59-183)	12.0	1.00

RT = response time, FE = Flanker effect.

Table 3.8 shows the results of activity group comparisons on flanker task performance. Mann-Whitney *U*-tests revealed no group differences when comparing video game players and non-players and when comparing musicians and non-musicians.

Within the exercise group comparisons, several significant group differences were identified. First, the participants who participated in exercise activities (M = 661.94 ms) had faster overall reaction time compared to participants who did not participate in these activities (M = 879.27 ms), U = 1.0, $p < .05$. RT advantage for the exercise group also appeared on congruent trials (M = 654.01 ms; non-exercise group: M = 883.46 ms), U = 0.5, $p < .05$.

Finally, a significant difference was identified between the exercise group (*M* = 63.27 ms) and the non-exercise group (*M* = -32.99 ms) on the flanker effect, *U* = 1.0, *p* < .05. A negative flanker effect, as seen in the group without regular exercise activities, indicates that participants were responding faster to incongruent trials compared to congruent trials.

Table 3.8 Comparison of activity groups on the flanker task.

	VG **n = 7**	**Non-VG** **n = 3**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Total accuracy (%)	94 (88-100)	95 (90-100)	9.0	.729
Congruent accuracy (%)	92 (83-100)	98 (95-100)	5.0	.190
Incongruent accuracy (%)	97 (90-100)	91 (84-100)	5.5	.221
Average RT (ms)	713.12 (536-939)	759.85 (664-939)	10.0	.909
Congruent RT (ms)	687.48 (502-900)	805.35 (666-964)	5.5	.253
Incongruent RT (ms)	729.66 (520-932)	777.49 (702-892)	9.0	.732
FE on RT (ms)	42.17 (-59-183)	16.24 (-72-85)	9.0	.732

	Music	**Non-Music**		
	n = 4	**n = 6**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Total accuracy (%)	97 (90-100)	93 (88-98)	5.5	.161
Congruent accuracy (%)	96 (90-100)	93 (83-100)	9.0	.504
Incongruent accuracy (%)	99 (95-100)	93 (84-100)	5.5	.137
Average RT (ms)	658.26 (536-756)	773.06 (550-939)	5.0	.136
Congruent RT (ms)	642.21 (502-753)	776.60 (544-964)	4.0	.087
Incongruent RT (ms)	691.75 (544-812)	778.84 (520-932)	6.0	.201
FE on RT (ms)	49.54 (36-60)	24.29 (-72-183)	8.0	.394

	Exercise	**Non-Exercise**		
	n = 7	**n = 3**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
Total accuracy (%)	95 (88-100)	92 (88-98)	6.5	.356
Congruent accuracy (%)	94 (83-100)	95 (84-100)	8.0	.551
Incongruent accuracy (%)	97 (90-100)	91 (84-100)	5.5	.221
Average RT (ms)	661.94 (536-774)	879.27 (760-939)	1.0	**.030**
Congruent RT (ms)	654.01 (502-786)	883.46 (786-964)	0.5	**.022**
Incongruent RT (ms)	698.38 (520-863)	850.47 (727-932)	3.0	.087
FE on RT (ms)	63.27 (-23-183)	-32.99 (-72-32)	1.0	**.030**

RT = response time, FE = Flanker effect.

3.5. Working memory task results

Table 3.9 shows span and score results from the forward-span and backward-span working memory tasks for the monolingual and bilingual groups. Table 3.10 shows the same results for participants who did and did not engage in EF-enhancing activities. Using Mann-Whitney *U*-tests, no significant group differences were identified on these tasks.

Table 3.9 Comparison of bilingual and monolingual groups on working memory tasks.

	Bilingual **WMF: n = 6** **WMB: n = 5**	**Monolingual** **WMF: n = 3** **WMB: n = 4**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
WMF span	3.33 (2-5)	3.67 (3-4)	7.5	.683
WMF score	56.17 (12-101)	54.00 (36-80)	9.0	1.00
WMB span	2.80 (2-4)	2.75 (2-4)	10.0	1.00
WMB score	42.00 (24-72)	40.25 (20-72)	8.0	.620

WMF = forward-span working memory task, WMB = backward-span working memory task.

Table 3.10 Comparison of activity groups on working memory tasks.

	VG **WMF: n = 6** **WMB: n = 7**	**Non-VG** **WMF: n = 3** **WMB: n = 2**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
WMF span	3.67 (2-5)	3.00 (2-4)	5.5	.341
WMF score	60.17 (24-101)	46.00 (12-76)	7.0	.606
WMB span	2.71 (2-4)	3.00 (2-4)	6.0	.743
WMB score	39.00 (20-72)	49.00 (26-72)	4.0	.374

	Music **WMF: n = 4** **WMB: n = 4**	**Non-Music** **WMF: n = 5** **WMB: n = 5**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
WMF span	3.25 (2-5)	3.60 (2-4)	7.5	.519
WMF score	52.75 (24-101)	57.60 (12-80)	9.0	.806
WMB span	2.50 (2-4)	3.00 (2-4)	7.0	.411
WMB score	33.00 (20-62)	47.80 (24-72)	5.0	.215
	Exercise **WMF: n = 6** **WMB: n = 7**	**Non-Exercise** **WMF: n = 3** **WMB: n = 2**		
Measure	Mean (range)	Mean (range)	*U*-value	*p*-value
WMF span	3.50 (2-5)	3.33 (2-4)	8.5	.892
WMF score	61.17 (24-101)	44.00 (12-74)	5.0	.302
WMB span	2.86 (2-4)	2.50 (2-3)	6.0	.743
WMB score	42.86 (20-72)	35.50 (26-45)	6.5	.882

VG = video games, WMF = forward-span working memory task, WMB = backward-span working memory task.

3.6. Correlational analysis

Table 3.11 shows Spearman’s rank order correlation results for background measures and overall and incongruent measures on executive function tasks. Only variables that are theoretically linked will be examined and discussed. Due to the small sample size of this study, results should be interpreted with caution. Furthermore, the strength of the correlations was considered and discussed, regardless of statistical significance. These correlations are based on all participant data and were not divided by language group or EF-enhancing activity groups.

Table 3.11 Correlational analysis of matching measures and EF task results.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Age (months)												
2. KBIT: SS	-.28											
3. PPVT: SS	-.25	.69*										
4. ST: Acc. Overall	-.01	.57	.00									
5. ST: Acc. Incongruent	.07	.60	.03	.96*								
6. ST: RT Overall	-.55	-.06	.36	-.49	-.60							
7. ST: RT Incongruent	-.52	-.40	.13	-.70*	-.80*	.82*						
8. ST: SE	.07	-.79*	-.52	-.34	-.38	-.10	.43					
9. FT: Acc. Overall	.71*	-.11	-.26	.04	.19	-.44	-.48	-.15				
10. FT: Acc. Incongruent	.72*	-.06	-.03	.08	.19	-.35	-.31	.03	.79*			
11. FT: RT Overall	-.72*	.08	.41	-.48	-.57	.90*	.75*	-.21	-.49	-.55		
12. FT: RT Incongruent	-.82*	.10	.36	-.27	-.36	.77*	.69*	-.10	-.44	-.50	.92*	
13. FT: FE	-.14	.69*	.43	.74*	.70*	-.24	-.35	-.27	.01	.14	-.21	.02

SS = standard score, ST = Simon task, Acc. = accuracy, RT = response time, SE = Simon effect, FT = flanker task, FE = flanker effect; asterisk (*) indicates significant correlation at the 0.05 level (*p* < .05).

Accuracy on the Simon and flanker tasks appeared to be differentially associated with both age and non-verbal intelligence. Simon task accuracy showed a moderately strong, positive correlation with KBIT performance ($r_s(8) = .57$, *n.s.*). Furthermore, there was a strong, negative correlation between the Simon effect and KBIT scores (r_s (8) = -.79, p < .05). Flanker task accuracy, in comparison, showed a strong, positive correlation with age (r_s (8) = .71, *n.s.*). Conversely, the relationships between the Simon accuracy and age (r_s (8) = -.01, *n.s*), and flanker accuracy and KBIT scores (r_s (8) = -.11, *n.s*) were very weak to weak.

RTs for both the Simon and flanker tasks, on the other hand, showed moderately strong to strong, negative correlations with participant age (Simon task: r_s (8) = -.55, *n.s.*; flanker task: r_s (8) = -.72, $p < .05$). RTs for both tasks also tended to show moderate to moderately strong negative correlations with task accuracy (Simon task: r_s (8) = -.49 to -.60 , *n.s.*; flanker task: r_s (8) = -.49 to -.55 , *n.s.*).

3.7. Select participant results

It is worth reiterating that the group comparison and correlational results should all be interpreted with caution due to the small sample size in this study. In order to make the best use of the data available, interesting results from individual participants will be described and later discussed in the context of EF development in children with ASD. Table 3.12 shows the background assessment results, and Simon and flanker task data from participants 4, 8 and 9.

Table 3.12 Background measures and EF task results for select participants.

	Participant 4	Participant 8	Participant 9
Age (months)	76	79	131
KBIT Standard Score	139	89	86
PPVT Standard Score	123	87	80
Groups	M, VG, E	B	M, VG, E
Simon Task			
Total accuracy (%)	97	71	88
Congruent accuracy (%)	100	90	100
Incongruent accuracy (%)	94	50	75
Overall RT (ms)	915.46	1025.78	727.17
Congruent RT (ms)	883.60	989.94	638.70
Incongruent RT (ms)	952.94	1097.44	845.13
SE on RT (ms)	69.34	107.50	206.43
Flanker Task			
Total accuracy (%)	88	90	98
Congruent accuracy (%)	83	100	95
Neutral accuracy (%)	85	89	100
Incongruent accuracy (%)	95	84	100
Average RT (ms)	773.62	939.32	550.42
Congruent RT (ms)	679.27	963.93	543.58
Neutral RT (ms)	762.76	963.38	586.90
Incongruent RT (ms)	862.50	892.19	520.45
FE on RT (ms)	183.23	-71.75	-23.13

B = bilingual, M = monolingual, VG = plays video games, Mus = attends music lessons, E = participates in exercise activities, RT = reaction time, SE = Simon effect, FE = flanker effect.

4. Discussion

The aim of the current study was to investigate the impact of certain experiences on the EF abilities of children with ASD. First, the study compared a group of children with ASD with single-language exposure to a group with dual-language exposure on a number of measures of EF. This line of inquiry follows from the literature postulating a bilingual advantage in EF in TD children and the literature finding that bilingual language exposure does not adversely affect other areas of development (i.e.: language acquisition) in children with ASD. Next, the participants with ASD were re-grouped based on their involvement in activities that have been implicated in improving EF skills, including playing video games, taking music lessons, and participating in regular exercise activities. In previous research on these activities, it has been found that individuals with deficits in EF were able to make the gains on EF tasks from these activities, making them meaningful routes of investigation for children with ASD.

Several hypotheses were put forward for this study. First, it was hypothesized that the bilingual children with ASD would do better at inhibiting task-irrelevant, conflicting information, leading them to have better performance, either globally or specific to incongruent conditions, on the Simon task and the flanker task when compared to their monolingual peers. This hypothesis was not supported by the results. Monolinguals tended to do better on congruent accuracy in the Simon task, and bilinguals tended to do better on congruent accuracy in the flanker task. It was also hypothesized that the bilingual group would have greater performance on the working memory tasks compared to their monolingual peers. This hypothesis was not supported by the results.

Next, it was hypothesized that children who engage in certain activities suggested to improve EF skills (i.e.: video games, music lessons, and/or regular exercise) would also have better performance on the Simon task and the flanker task compared to those who do not engage in these activities. The results indicate mixed support for this hypothesis. Finally, it was hypothesized that children engaging in these activities would have better performance on the working memory tasks. This hypothesis was not supported.

The following sections will discuss the results in greater detail including the theoretical impact of these findings. Select participant results will also be discussed in the view that they may illustrate EF development in children with ASD. Limitations of the study and suggestions for future directions of research will also be discussed.

4.1. Lack of support for the bilingual advantage in children with ASD

By carrying out this study on a population of children with ASD diagnoses, there are inherent differences between this sample and samples used in previous research on TD children. In other words, the participants in this study will have exhibited symptoms of autism which may have impacted their performance on the tasks, whereas this is likely untrue for participants in most studies. The potential impact of social-communication deficits that are inherent to ASD was controlled for by making all experimental tasks computer-based, minimizing the need for the participant to balance social-communication demands with the EF demands of the task.

Other differences between this sample and other participant samples are not necessarily inherent to ASD, but are related. The prevalence of both intellectual disability and language impairment is higher within the ASD population compared to the general population (Christensen et al., 2016; Kjelgaard & Tager-Flusberg, 2001). On the other hand, ASD is often associated with intellectual giftedness, specifically in the non-verbal domain and particularly when the child is considered to be "high-functioning" (Burger-Veltmeijer & Minnaert, 2011). We see these patterns mirrored in the current study's sample with the wide range of standard scores on the PPVT and KBIT measures.

Despite the increased variation in this sample, the sample's mean standard scores for the PPVT and the KBIT fall within the normal range. Although the difference was not statistically significant, the bilingual group's PPVT score was lower than that of the monolingual group, but this is a commonly-replicated finding in research comparing a monolingual group to a bilingual group (Bialystok et al., 2010).

4.1.1. Simon task performance

This study's results for accuracy on congruent and incongruent trials mirrored the pattern found in studies of TD children. Overall, participants were more accurate on congruent tasks compared to incongruent tasks, a difference that met statistical significance. This pattern is a robust finding in Simon task research (Morton & Harper, 2007; Struys et al., 2015).

However, in terms of group comparisons, rather than finding greater accuracy for the bilingual group, this study found that the monolingual group had higher accuracy, but only on congruent trials. As discussed in the introduction, when the Simon task is used with TD children, the findings tend towards bilingual advantages on all trial types (Bialystok, Martin, et al., 2005; Martin-Rhee & Bialystok, 2008; Struys et al., 2015). Monolingual advantages have been found in a few studies of adults (e.g.: Paap & Greenberg, 2013), but the finding of a monolingual advantage specific to congruent trials has not been reported in the available literature on bilingualism and EF in TD children. These results cannot be interpreted as the monolingual group having superior inhibition skills compared to the bilinguals, as congruent trials do not target inhibition. Incongruent trials target EF because the participant must resolve the *interference* from cues that provide discrepant information. Better performance on congruent trials would indicate that these participants are better able to make use of the *facilitation* of the cue congruence.

Looking at the overall RT data, the younger participants were comparable to previous research on TD children, but the older participants were slower. Looking at the youngest participants (6-7 years), their mean RTs on congruent (*M* = 849.53 ms) and incongruent (*M* = 933.48 ms) trials were similar, or even faster, compared to those found in a sample of TD six- and seven-year-olds in Morton and Harper (2007; congruent mean RT = 901.4-947.2 ms; incongruent mean RT = 980.8-1099.0 ms). However, the older participants in this study (8-10 years) were slower on both congruent (*M* = 748.41 ms) and incongruent (*M* = 835.79 ms) trials when compared to the TD eight- to ten-year-old sample in Struys et al. (2015; congruent mean RT = 656.0-667.8 ms; incongruent mean RT = 705.4-706.0 ms). ASD is associated with deficits in praxis (Dzuik et al., 2007), which may account for these slower RTs.

Turning to the Simon effect, the difference between congruent and incongruent trials also met statistical significance, indicating that the participants were responding faster to congruent trials compared to incongruent trials. This difference, the Simon effect, is a robust finding in studies of TD children (Martin-Rhee & Bialystok, 2008; Morton & Harper, 2007). This also indicates that slower RTs in some participants did not affect response differences to the different trial types.

Looking at group differences, the Simon effect in this study was found to be 68.78 ms for the bilingual group and 112.70 ms for the monolingual group. This difference was not identified as statically significant. It is difficult to determine whether these numbers are consistent with the literature, as the size of the Simon effect varies from study to study, and all of the research so far has been conducted on typically-developing children. Martin-Rhee and Bialystok (2008) found a Simon effect of approximately 250 ms for both bilingual and monolinguals children. Morton and Harper (2007) found a mean Simon effect of 151.8 ms for bilingual children and 79.4 ms for monolingual children. The most plausible explanation for the lack of significant Simon effect overall and lack of difference between groups is the high degree of variation within the sample, as discussed earlier. With Simon effects ranging from virtually nil (participant 5: -0.89 ms) to rather large (participant 9: 206.43 ms), no clear pattern was able to emerge.

4.1.2. Flanker task performance

When the flanker task data was analyzed across all participants, there was no effect of congruence on either accuracy or RT. Some studies with children do not find an effect of congruence on accuracy due to a ceiling effect (Engel de Abreu et al., 2012; Poarch & Bialystok, 2015). This is likely the case in this study as well. The mean accuracy for the flanker task was 94%. This high degree of accuracy coupled with the small sample size likely dampened any variation between trial types that might have been detected as an effect of congruence. Other the other hand, the flanker effect is a very robust finding in studies of TD children (Engel de Abreu et al., 2012; Kapa & Colombo, 2013; Nicolay & Poncelet, 2012; Poarch & Bialystok, 2015).

One explanation for why no effect of congruence was found on the flanker task may have to do with stimulus overselectivity. Stimulus overselectivity occurs when a participant over-attends to a small piece of available information, ignoring other available stimuli. This pattern of processing is associated with ASD, although recent research has found that it also occurs in young TD children (Dube et al., 2016; Rieth, Stahmer, Suhrheinrich, & Schreibman, 2015). This may have affected flanker task performance, as the distracting information was external to the target stimuli, making it possible for the participant to ignore it altogether and to remain focused on the target stimulus alone throughout the whole task. The Simon task, on the other hand, likely would not be affected by this maladaptive strategy, as the distracting cue was incorporated into the goal-related cue.

Compared to previous research on TD children, both the younger and older participants' RTs on congruent and incongruent trials were comparable, or somewhat faster. The younger participants (6-7 years) had a mean RT of 809.86 ms on congruent trials and 831.12 ms on incongruent trials. This was faster than what was reported for a sample of TD six-year-olds in Ladas et al., (2015; congruent mean RT = 855-868 ms; incongruent mean RT = 921-937 ms). The older participants (8-10 years) had a mean RT of 685.55 ms on congruent trials and 706.67 ms on incongruent trials. This was comparable, or faster, than the RTs reported in most studies of TD children around this age. Engel de Abreu et al. (2012) found mean congruent RTs of 734-838 ms and mean incongruent RTs of 776-940 ms. Poarch & Bialystok (2015) reported mean congruent RTs of 665-699 ms and mean incongruent RTs of 748-769 ms. Deficits in praxis did not appear to be affecting this sample's performance on the flanker task.

In terms of group comparison, the bilinguals performed better than monolinguals on congruent trials accuracy. While the better performance for the bilingual group compared to the monolingual group is consistent with flanker task findings in TD children, the fact that the advantage was specific to congruent trials is not consistent with enhanced EF skills. Similar to the monolingual group findings in the Simon task, it appears as though the bilingual group in the flanker tasks was better able to make use of the *facilitation* provided by cue congruence, but not better able to resolve cue *interference*. Unlike the Simon task, the flanker task has neutral trials that should make it possible to separate these effects. However, no differences were found between congruent and neutral trials on the flanker task. Further exploration of this finding is beyond the scope of this small-sample study.

The flanker effect in this study was 30.53 ms for the bilingual group and 40.18 ms for the monolingual group, a difference that was not significant. These are smaller flanker effects than what has been found in TD children (Engel de Abreu et al., 2012: 104-164 ms; Nicolay & Poncelet, 2012: 172-174 ms). While it appears as though the participants in the current study were not as affected by the misleading flanker information as participants in other studies might be due to stimulus overselectivity, another factor is the presence of several participants with negative flanker effects. A negative flanker effect indicates that the participant is responding faster to incongruent trials compared to congruent trials. Unlike the single participant with a negative Simon effect, which was virtually nil (participant 5: -0.89 ms), there were three participants with negative flanker effects have sizeable negative flanker effects: participant 8 (-71.75 ms), participant 9 (-23.13 ms), and participant 12 (-59.04 ms). The explanation of a speed-accuracy trade-off can be rejected, as only RTs for accurate trials were analyzed. Additionally, accuracy was high (≥88%) for all participants on the flanker task.

A similar pattern emerged in Bialystok's (2006) study of adult bilinguals and computer video game players. In the low-switch condition (15/40 or 37.5% of trials required a response switch), congruent trials had faster RT compared to incongruent trials for all participants, but in the high-switch condition (28/40 or 70% of trials required a response switch), the effect of congruence reversed in one of the tasks and became null in the other task. Given that this study used a random trial order, the number of response switches was variable between participants, with switch trials accounting for 47-67% of trials. However, only one of the participants with negative flanker effects had a percentage of switch trials comparable to Bialystok's (2006) high-switch condition; participants 8 had 63% switch trials. Other participants with switch percentages in the high sixties, however, still had positive flanker effects. The other two participants with negative flanker effects had lower switch percentages than what would be comparable to Bialystok's (2006) study; participant 9 had 57% switch trials and participant 12 had 47% switch trials. This phenomenon cannot, at this time, be accounted for based on the findings of this study, although this may be an autism-specific finding.

4.1.3. Working memory task performance

The working memory task was particularly difficult for the participants in this study. Of the three younger participants in this study (ages 6;4-6;8), one did not complete the forward-span working memory task and one did not complete the backward-span task. The ones who only completed one of the tasks only achieved a span of two on the task they did complete. The one younger participant who completed both working memory tasks achieved a span of 4.0 on both. This one participant is comparable to the span of 3.2-3.8 reported for the TD five- and seven-year olds in Morales et al. (2013); the other two younger participants had poorer working memory performance than this study's sample. Although older than the participants in Morales et al. (2013), the older participants in this study (ages 8;8-10;11) achieved a mean span of 3.57 which is also comparable to their results. Morales et al. (2013) did not use a backwards-span condition. Calvo and Bialystok (2014) did not report the mean span on the FMT for their sample of TD children.

While the differences between performance in this study and Morales et al. (2013) and Calvo and Bialystok (2014) may have been due to deficits in spatial working memory specific to ASD (Boucher et al., 2012), the differences may have also been due to task differences between the studies. The tasks in these two studies were more child-friendly and resembled more closely a computer game, which may have been more appealing to the participants in their studies.

4.1.4. Theoretical implications

Within the bilingualism and EF literature, the Simon task and flanker task are discussed as if they were roughly equivalent. This equivalence is not well supported by the group comparison results and the correlational results in this study. If the flanker and Simon tasks were measuring the same construct, one would expect to see similar results on both accuracy and RT across group comparisons. There is some bilingualism literature separating the underlying mechanisms tapped by each the Simon and the flanker tasks (Paap & Greenberg, 2013; Paap & Sawi, 2014). This further supports the need for more careful definition of the types of inhibition being measured by the tasks used in studies of EF and bilingualism.

Furthermore, the discrepant findings of these tasks provide evidence that the skills targeted by each of these tasks are differentially affected in children with ASD. In previous research, Christ et al. (2007) found that performance on tasks of intrinsic inhibition (i.e.: when the distracting element is intrinsic to the target stimulus) and tasks of extrinsic inhibition (i.e.: when the distracting element is external to the target stimulus) can be differently affected in children with ASD with EF deficits. Additionally, stimulus overselectivity may affect performance on one set of tasks (i.e., tasks of extrinsic inhibition) but not another set of tasks (i.e., tasks of intrinsic inhibition). Tasks used to measure EF skills in TD samples may not be equivalently applicable to research with children with ASD.

Additionally, previous research has found that those with greater deficits in EF tend to benefit most from activities that enhance EF skills (Flook et al., 2010). This is found in the bilingualism literature as well. The differences found in the bilingualism literature are most consistently observed in studies of children, who are in the process of developing their EF skills, or in studies of older adults, who are in the midst of EF decline (Bialystok, Martin, et al., 2005). Therefore, if there is an EF-specific advantage for bilinguals, one might expect to find benefits in a study of children with ASD, a population that tends to experience EF deficits. The current study did not find such an advantage. Should the findings from this study be replicated in a larger sample study, this would raise doubt regarding the EF-specific bilingual advantage.

4.2. Mixed support for advantages associated with EF-enhancing activities

Similar to the findings for the bilingual and monolingual group comparisons, these results are exploratory in nature, and, given the small sample size and uneven groups, need to be replicated in a larger study before definite conclusions can be drawn. That said, few group differences emerged, and when they did, they were restricted to a single task.

Comparing video game players to non-players, the results do not indicate that playing video games is associated with an increase in performance on EF tasks. No group differences were found on either task of inhibition or either task of working memory. The research available on video games and EF tends to find that benefits are specific to cognitive skills trained by the type of games being played. For example, Mackey et al. (2011) found that children who played computer games that focused on speed showed RT improvements over time, while those who played games that focused on reasoning showed improvements in that area. The majority of the children in the video games group played games that did not include some sort of speed component (i.e.: *Minecraft*, a 3D building game), so the lack of group differences may be related to this lack of skill-specific training.

Next, comparing the participants who take music lessons compared to those who do not, the results are mixed. Similar to the video game findings, no group differences were found on either task of inhibition or either task of working memory. Previous research investigating the link between musicianship and EF often used visual and aural tasks of inhibition (Bialystok & DePape, 2009; Degé et al, 2011). The current study used only visually-presented tasks which might account for the discrepant findings. It is also possible that children in this age group have not played music for long enough to gain the EF benefits associated with musicianship.

Finally, the comparisons between the participants who do and do not engage in regular exercise provided interesting results. In the Simon task, the participants who exercise had significantly higher overall and incongruent trial accuracy compared to those who do not.

These results support the hypothesis that engaging in regular exercise improved EF, but would require replication on a larger sample with more balanced groups. The findings from this task are consistent with the literature finding a positive association between regular exercise and EF abilities in children with EF deficits (Chang et al., 2012; List Hilton et al., 2014).

Looking at the flanker task results, participants who exercise had significantly faster RT overall and for congruent trials. These results indicate a general speed advantage for these participants, but not necessarily better EF. Similar to the bilingual/monolingual group comparisons discussed above, the lack of group differences on incongruent trials indicates that the dissimilar performance was not due to EF differences. The flanker effect was significantly different between the two groups, with the exercise group showing a larger effect (63.27 ms) compared to the non-exercise group (-32.99 ms). This negative flanker effect, as discussed previously, cannot be accounted for within the scope of this study. Finally, no group differences were found on either task of working memory, similar to the other group comparisons.

4.3. Analysis of individual participant data

While the group comparison findings are limited due to small sample size and uneven group numbers, a number of participants in this study provide interesting cases for the study of inhibition in children with ASD. The participants chosen represent maximally different scenarios in the development of EF in children with ASD. Participant 8 had scores in the normal range for nonverbal intelligence and receptive vocabulary. He had relatively lower parental education (compared to this sample) and did not participate in any of the EF-supporting activities examined in this study. Participant 4, the youngest in the sample, had high scores on nonverbal intelligence, receptive vocabulary, had highly-educated parents, and participated in many exercise activities. Finally, participant 9 had borderline-to-below average scores on non-verbal intelligence and receptive vocabulary, but participated in exercise activities, was the oldest participant in the sample, and had relatively lower parental education. Identifying information has been removed in order to ensure participant anonymity.

4.3.1. Participant 8

Participant 8 (6 years old) was chosen as a case study for several reasons. He scored within the average range for both non-verbal intelligence (KBIT SS=89) and receptive vocabulary (PPVT SS=87). Although he was exposed to two languages from birth, his primary caregiver rated most of his language skills in both as below *functional* on the language history questionnaire. His parents were on the low end of degree of parental education compared to the rest of the sample. He does not play video games, play music, or exercise regularly. Since receiving his ASD diagnosis over a year ago, he has received a total of eight hours of intervention services.

This participant completed the Simon task first and achieved 71% overall accuracy on the Simon task. In addition to having low accuracy on the Simon task, he had the slowest average RT in the sample (1025.78 ms). As can be seen in Figure 4.1, this participant made a number of errors even with increased latency of RT. However, his accuracy did improve when he took longer than 1100 ms to respond. Additionally, this participant had the largest effect of congruence on accuracy. His congruent accuracy was 90% and his incongruent accuracy was 50%. His errors on incongruent trials appear throughout the range of RTs. While longer latencies did appear to improve his performance, trials that exceed the 1100 ms point were in the minority. It does not appear as though this participant was able to self-impose the necessary "wait-time" needed for inhibition to catch up to his impulsive response.

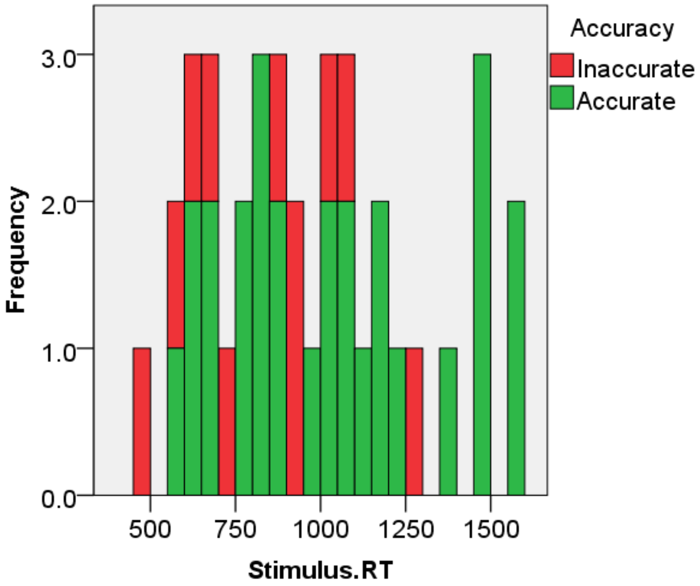

Figure 4.1 Participant 8's errors by RT.

The flanker task showed similar results. Although his accuracy improved overall to 90%, his errors were similarly spread throughout the range of RTs. Also similar to his performance on the Simon task, he had a relatively large discrepancy between congruent and incongruent accuracy (100% and 84%, respectively). Although his negative flanker effect (-71.75 ms) indicated that his responses to incongruent trials were faster than to congruent trials, errors on incongruent trials occurred throughout the range of RTs.

The results from both tasks support the proposition that this participant was at an early point in EF development. More similar to pre-school children, this participant made errors by impulsively responding according to the misleading stimulus cue (Diamond, 2002); however, he did not demonstrate the ability to self-impose the response latency required for better accuracy. He also did not demonstrate significant strategy adjustment between the Simon and flanker tasks, as he continued to respond quickly and make errors on the second task. This participant’s performance is consistent with research finding inhibition deficits (on both flanker and Simon tasks) in children with ASD (Robinson et al., 2009; Verté et al., 2005; c.f. Christ et al., 2007).

4.3.2. Participant 4

Participant 4 was chosen as a case study as he was the youngest participant in the sample (6 years), but achieved the highest KBIT score (SS=139) and the second-highest PPVT score (SS=123). He has only ever been exposed to English, although both of his parents speak multiple languages. His parents are both highly educated. In addition to his ASD diagnosis, he was diagnosed with pragmatic language impairment only one month before the testing session. He plays puzzle games on his iPad regularly (i.e., estimated 9 hours per week) and participates in more exercise than any other participant (estimated at 4 hours per week).

He completed the flanker task before the Simon task. His overall accuracy on the flanker task was only 88%, which was tied for the lowest of the sample. He had an average RT of 773.62 ms on accurate trials, and made most of his errors when he had RTs faster than 600 ms. More errors on faster trials is expected; however, what is unexpected about his performance is that he was much more accurate for incongruent trials (95%) compared to congruent trials (83%). While his accuracy on congruent versus incongruent trials was in the opposite direction from what is expected, he showed a flanker effect in the expected direction. It took him, on average, 183.23 ms longer to respond to incongruent trials compared to congruent trials. It appeared as though the interference from the incongruent trials forced him to slow down, which actually ended up helping his accuracy. When there was no interference and he responded quickly, he made more errors.

Looking at his performance across blocks of the flanker task, participant 4 made a roughly equal number of errors at the end of the task compared to the beginning, and he did not slow down his responses in order to improve his accuracy. Although online performance adjustments such as this are not a robust finding in TD children until the age of nine (Anderson, 2002), this participant had high KBIT and PPVT scores, indicating that he has other areas of development which are advanced for his age. However, the lack of evidence of online performance adjustments indicates that he had not developed this skill at the time of testing.

When presented with the Simon task, his performance shifted drastically. His RT slowed down to an average of 907.37 ms and his accuracy jumped to 97%. It is possible that he changed his strategy between tasks based on his flanker task performance, giving himself more time to respond and thus improving accuracy. Another possibility is that the flanker task and Simon task performance do not target the same skill, and that this participant was better at tasks of intrinsic inhibition compared to tasks of extrinsic inhibition. This would be consistent with findings of specific deficits in extrinsic inhibition in children with ASD (Christ et al., 2007).

4.3.3. Participant 9

Participant 9 was the oldest participant in the sample at 10 years old. He had a borderline score on non-verbal intelligence (KBIT SS=86) and a below average score on receptive vocabulary (PPVT SS=80). He was an English-speaking monolingual, although his mother speaks a second language. He receives educational support and speech-language pathology services through his school. He plays iPad games (estimated at 1 hour per week) and participates in a weekly fitness activity (1 hour per week). His parents have both completed some university/college coursework.

Participant 9 completed the flanker task first and achieved 98% accuracy. He made a single error on a congruent trial. In addition to his high accuracy, he had an average RT of 550.42 ms, the second-fastest in the sample. In contrast to the high accuracy attained by participant 4 on the Simon task, participant 9 did not have to sacrifice RT in order to achieve high accuracy. This is not surprising given participant 9's age; he has more efficient inhibition on this task.

When given the Simon task, he achieved 88% overall accuracy with an average overall RT of 727.17 ms, much faster than either participant 8 and 4. His errors occurred exclusively on trials with faster RTs (<500 ms). Furthermore, his errors occurred exclusively on incongruent trials. The logical conclusion is that on all trials with RTs faster than 500 ms, this participant was responding solely based on the location cue and not inhibiting this impulsive response in order to respond based on the colour rule. However, on all trials with RTs slower than 500 ms, this participant demonstrated successful inhibition of the spatial cue, allowing him to respond based on the colour rule.

Given that RTs slower than 500 ms led to such a distinct improvement in this participant's performance, one could expect that this participant might make changes to his response behaviour over the course of the task in order to improve accuracy. Although he was past the age at which typically-developing children are able to monitor their task performance (Anderson, 2002), this participant's KBIT score was almost 1SD below the mean for his age (SS=86) and his PPVT score was more than 1SD below the mean for his age (SS=80). Figure 4.2 shows this participant's mean RT for each block of the Simon task. There is a trend of slower RTs as the task continued, indicating that, unlike participant 4, this participant was making online adjustments to his response behaviours in favour of slower RTs.

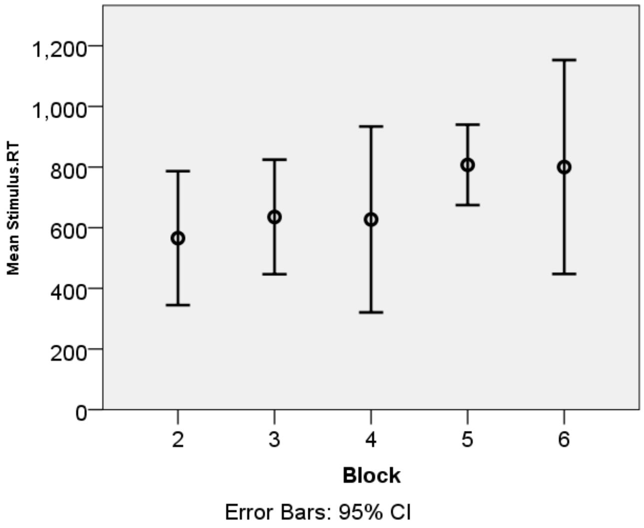

Figure 4.2 Participant 9's Simon task mean RT for task blocks.

However, slower RTs could also indicate fatigue or boredom. This explanation is further supported by the fact that this participant completed the flanker task first, and thus was doing the Simon task at the end of the two-hour session. If, in fact, this shift towards slower RTs was helping him to achieve higher accuracy, one would expect to see higher accuracy with each block of the task. If the cause of the slower RTs was fatigue or boredom, accuracy is likely to either stay stable or decrease. Figure 4.3 shows the number of accurate and inaccurate trials for each block of the Simon task. The participant's accuracy shows an increasing trend, reaching 100% in the final two blocks of the task. This indicates that this participant was making online adjustments to his response behaviour in order to increase accuracy.

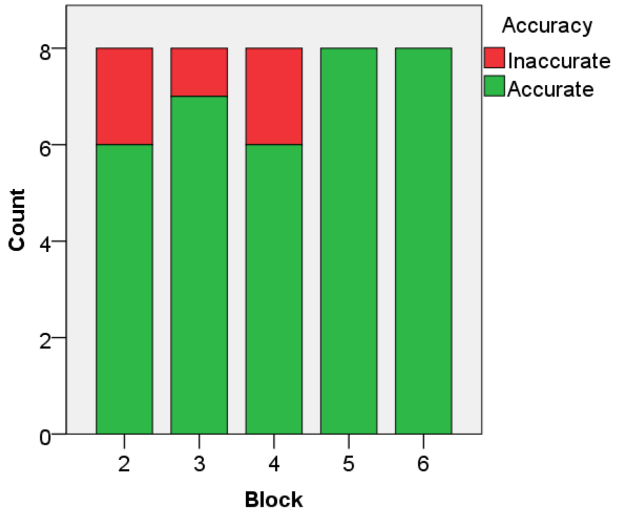

Figure 4.3 Participant 9's Simon task mean accuracy for task blocks.

A final indicator that this participant was adjusting his performance consciously, as opposed to as a result of fatigue or boredom, is evident in the decreased Simon effect as the task goes on. In the first block of trials, participant 9 had a Simon effect of 288.25 ms which decreased to 106.75 ms by the final block of trials. This participant was finding an efficient way to improve his accuracy on this task, by increasing his RT on *all* trials, not just incongruent trials. While congruent trials remained faster than incongruent trials, the RTs have leveled off and accuracy improved.

4.3.4. Summary of participant analysis

These three cases of children with ASD represent three unique profiles of inhibition skills. Participant 8 had poor performance on both the Simon and flanker tasks. Specifically, although his accuracy was higher on trials with RTs longer than 1100 ms, the trials where this occurred were in the minority, indicating that this participant was not using a strategy in order to favour accuracy over speed. This pattern of performance is observed in TD pre-school age children (Diamond, 2002). In contrast, participant 4, who was younger, had higher PPVT and KBIT scores, and had access to many EF-enhancing experiences, did demonstrate strategically slower RTs on more difficult trials in order to improve accuracy. Finally, participant 9, the oldest of this group, not only showed the use of a strategy, but also the refinement of this strategy as the task continued. This online strategy adjustment is found in TD children around age nine (Anderson, 2002). These results support the notion that children with ASD may experience EF difficulties, but that the extent to which each child experiences them is variable. Age and access to EF-supporting experiences likely contribute to this variation. These results could also been seen as evidence for developmental changes in children with ASD. EF skills are likely to follow an improving course as the child develops. In other words, the development of EF skills of children with ASD may be delayed as opposed to disordered.

4.4. Limitations

The most significant limitation of the current study is the small sample size. Related to this problem is the problem of uneven participant numbers in each group. This was a severely limiting factor in the study’s ability to detect group differences. The presence of outliers, the differences in distributions between groups, and the inability to reliably interpret test of normality led to the use of nonparametric analyses, which are more conservative in their rejection of the null hypothesis.

A second and related limitation of this study is the heterogeneous nature of the participants. One place where this is most evident is the wide range of ages of the participants in this study (6 years, 4 months to 10 years, 11 months). Significant EF and general cognitive development occurs during this age span (Diamond, 2002), which emerged as more of a problem than anticipated given the small sample. This variability within the sample could have masked group differences.

Related to this, another area where heterogeneity could have been introduced into the sample is through the lack of symptom-severity criteria for inclusion in the study. Often, research focusing on populations with development disorders imposes a criteria for minimum or maximum severity of symptoms. For example, research on children with ASD is often restricted to participants who meet the criteria of “high-functioning autism.” Not only does this help to ensure that all participants will be able to complete the tasks, it also helps to control for the degree of impact the participant’s disorder or disability may have on the results. In this study, no such controls were put in place. Efforts were made to control for this by implementing nonverbal intelligence and receptive vocabulary matching measures; however, given the small sample, strict cut-offs were not able to be used. The consequence is greater variability of skills and abilities within the participant group, potentially masking any group differences.

Previous research on bilingualism and EF has imposed stricter criteria for bilingualism. Research conducted with typically developing populations often seek “ideal” bilingual participants who have been exposed to both of their language since birth, who have developed expressive proficiency in both languages, and who have continued to use both languages in their everyday lives without interruption. The current study had more lenient criteria for inclusion in the bilingual category (i.e.: exposure to two languages, with at least 30% exposure to each language, for at least the past two years). Included in the bilingual group were two participants who learned a second language through French Immersion programs. Although there is evidence that classroom bilingualism still imparts EF advantages (Nicolay & Poncelet, 2013), the impact of the differences between early and late bilinguals may have increased in importance due to the small sample.

In contrast to the high degree of variation seen in the participants and their performance on the Simon and flanker tasks, there was a lack of variation of performance on the working memory tasks. Out of the ten participants, two did not complete the second working memory task after the first one had been completed. Based on informal observation of these participants during data collection, the refusals were likely due to the participants' frustration with the first task and the expectation that the second task would be of similar or increased difficulty. Of the remaining eight participants who did complete both working memory tasks, only one achieved a working memory forward-span of five. All other participants' results fell between two and four. Based on the low cluster of results and informal observation, it is the author's opinion that the spatial forward-span and backward-span working memory tasks selected for this study were too difficult. This clustering of results in such a small sample would make it improbable that any group differences could be detected.

A final limitation of this study is common to many studies of EF; EF tasks have questionable construct validity. There is insufficient research to support the notion that the tasks most commonly used to investigate sub-components of EF actually measure what they purport to measure. Researchers who discuss this problem in the bilingualism literature (e.g:

Paap & Greeberg, 2013) often point to the need to use more than one task in order to evaluate convergent validity. Two tasks of inhibition were used in this study, and each task found discrepant results. Subsequently, efforts were made throughout to discuss these tasks relatively separately and not collapse the results inappropriately.

4.5. Future Directions

Continued research into the impact of dual language exposure on the cognitive development of children with ASD is warranted. The current study attempted to address whether the bilingual advantage for EF skills found in TD children might also be applied to children with ASD, hypothesizing that it would. While the findings did not support this prediction, given the small sample size and the heterogeneous nature of the participants, the results cannot be confidently said to either support or refute this hypothesis. With both the number of children being diagnosed with ASD and the number of families who speak more than one languages on the rise in British Columbia and, on a larger scale in Canada, this is an important area of inquiry. During data collection for this study, many parents, regardless of whether they chose to raise their child with one or two languages in the home, asked if they had made the right decision. Professionals working with children with ASD would benefit from further research in this area in order to guide the advice they provide to parents regarding decisions around how many and which languages to use with their child with ASD.

Replication of this study with several modifications could provide more conclusive evidence regarding whether there are cognitive benefits to be derived from dual language exposure and/or activity involvement for children with ASD. A larger and/or more uniform sample would aid in increasing the power of the analyses. A larger sample would produce data that could be subject to tests of normality and, if appropriate, parametric statistical analysis. Participant inclusion criteria could encompass some or all of the following variables in order to control for factors known or suspected to affect EF development: a more restricted age range, severity ratings of ASD symptoms, simultaneous versus sequential bilingualism, and/or expressive ability in all languages. By addressing these factors during participant recruitment, participant variability is less likely to mask any group differences potentially as a result of single or dual language exposure.

Another improvement that could be made to the current methodology is the modification of the working memory tasks. The spatial-span tasks were used in order to accommodate a wide range of participant verbal abilities. As previously mentioned, severity of ASD symptoms was not controlled in this study, so all tasks were designed to ensure that even minimally verbal participants could complete the tasks. However, the spatial-span tasks were likely too difficult for the participants in this study. If severity of ASD symptoms or expressive language ability is controlled, a verbal working memory task could be used. Previous research has shown that children with ASD can complete verbal working memory tasks. With greater participant success, the results would likely disperse over a wider range, and one might be able to detect group differences, should they exist.

On a larger scale, the field of EF research would benefit greatly from improvements in the construct validity of tasks purported to measure specific sub-components of EF. As demonstrated by the negative correlation between accuracy on the Simon task and accuracy on the flanker task in this study, these tasks that are supposedly both measuring inhibition are likely tapping into different skills. Future research targeting the more precise defining of current EF tasks would help clarify existing results in EF research. Additionally, research investigating the appropriateness of currently used EF tasks for clinical populations, bearing in mind processing differences such as stimulus overselectivity, will help further our understanding of EF in those have deficits in this area.

Finally, based on the individual participant analysis, there is clearly a need for more research on the EF abilities of children with ASD. Three unique profiles of inhibition skills were identified within this small sample. Current research on children with ASD has focused on attempting to define the singular EF profile of children with ASD. What can be taken from the results of this small study is that by trying to identify a single pattern of EF abilities, current research may be missing the more important feature of individual variability. Pellicano (2010) compared each of thirty-seven children with ASD to the means of a TD group in order to investigate individual degrees of “atypicality.” She was able to determine how many children in the sample showed deficits in EF, theory of mind, central coherence, and any combination of the three. Her results highlighted variation in individual strengths and weaknesses within this population, and were more illustrative than looking at the group results for EF, theory of mind, and central coherence separately. Based on the results of the current study and the inconsistent research in this area, the study of EF in children with ASD could benefit from this more difference-centric approach.

4.6. Conclusion

The current study advanced several hypotheses: that bilingual children with ASD would out-perform monolingual children with ASD on tasks of inhibition and working memory, and that children with ASD who engage in certain activities suggested to improve EF would out-perform children who do not engage in said activities in tasks of inhibition and working memory. The results ranged from an outright lack of support to mixed support of the hypotheses; however, this study's ability to make group comparisons was limited by small sample size and significant variation among participants.

While the group comparisons did not provide unequivocal evidence in support of EF-enhancing experiences, improved performance on EF-specific conditions in the Simon task for the exercise group over the non-exercise group support the notion that regular exercise may support EF skills in children with ASD. Furthermore, in-depth analysis of the performance of select participants demonstrated the individual diversity of EF profiles within the population of children with ASD. Even within this small sample, participants with three unique performance profiles on tasks of inhibition were identified. This highlights the need for further research into the EF profiles of children with ASD, perhaps with an eye towards quantifying the variability within the population as opposed to attempting to fit the population with a single profile.

ASD professionals face questions about the benefits and drawbacks of bilingualism on regular basis when working with families of children with ASD, who are often given conflicting advice on whether single or dual language exposure is good or bad for their child. While it remains unclear whether dual language exposure positively impacts the EF skills of children with ASD, these lines of inquiry show that there are no negative consequences of bilingualism and will hopefully inspire future research in this area as the demand for high-quality evidence related to ASD, EF, and bilingualism increases.

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Appendix

THE UNIVERSITY OF BRITISH COLUMBIA

The University of British Columbia
Faculty of Medicine
School of Audiology and Speech Sciences

Participant Information Questionnaire

The Effects of Bilingualism on the Executive Functioning of Children with Autism Spectrum Disorder

Please complete the following questionnaire regarding your child's history of language exposure and/or use. It is important that the information we receive is as complete as possible. This information will be used to determine whether your child is an eligible participant for this research project and for data analysis purposes.

If you have any questions or concerns about any of the questions, please contact the co-investigator, Shelby Siroski at (604) 928-4094 or siroskis@alumni.ubc.ca, or the principle investigator, Stefka Marinova-Todd at (604) 822-0276 or stefka@audiospeech.ubc.ca.

Section 1. Contact and important information.

1. Child name:
2. Child date of birth:
3. Child gender:
4. Names of child's parent(s)/guardian(s)/primary caregiver(s):
5. Parent/guardian e-mail or phone #:
6. Mailing address:

DO NOT WRITE IN THIS SECTION.

Notes for interview: ____

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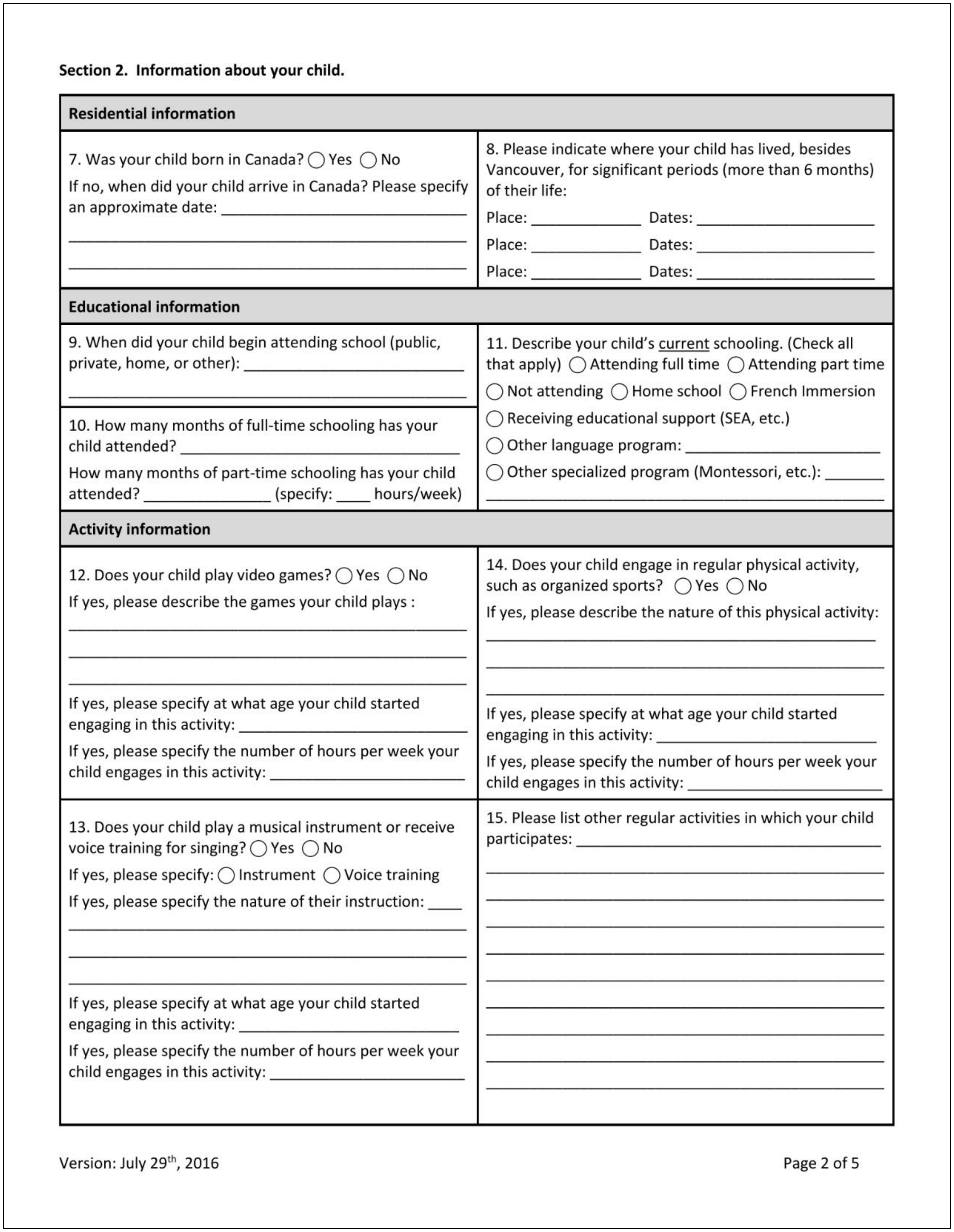

Section 2. Information about your child.

Residential information

7. Was your child born in Canada? ○ Yes ○ No

If no, when did your child arrive in Canada? Please specify an approximate date: ______________________________

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____

8. Please indicate where your child has lived, besides Vancouver, for significant periods (more than 6 months) of their life:

Place: _____________ Dates: _____________________

Place: _____________ Dates: _____________________

Place: _____________ Dates: _____________________

Educational information

9. When did your child begin attending school (public, private, home, or other): __________________________

____

10. How many months of full-time schooling has your child attended? __________________________________

How many months of part-time schooling has your child attended? _______________ (specify: ____ hours/week)

11. Describe your child's <u>current</u> schooling. (Check all that apply) ○ Attending full time ○ Attending part time

○ Not attending ○ Home school ○ French Immersion

○ Receiving educational support (SEA, etc.)

○ Other language program: _______________________

○ Other specialized program (Montessori, etc.): _______

____

Activity information

12. Does your child play video games? ○ Yes ○ No

If yes, please describe the games your child plays :

____

____

____

If yes, please specify at what age your child started engaging in this activity: ___________________________

If yes, please specify the number of hours per week your child engages in this activity: _______________________

14. Does your child engage in regular physical activity, such as organized sports? ○ Yes ○ No

If yes, please describe the nature of this physical activity:

____

____

____

If yes, please specify at what age your child started engaging in this activity: ___________________________

If yes, please specify the number of hours per week your child engages in this activity: _______________________

13. Does your child play a musical instrument or receive voice training for singing? ○ Yes ○ No

If yes, please specify: ○ Instrument ○ Voice training

If yes, please specify the nature of their instruction: ____

____

____

____

If yes, please specify at what age your child started engaging in this activity: ___________________________

If yes, please specify the number of hours per week your child engages in this activity: _______________________

15. Please list other regular activities in which your child participates: _____________________________________

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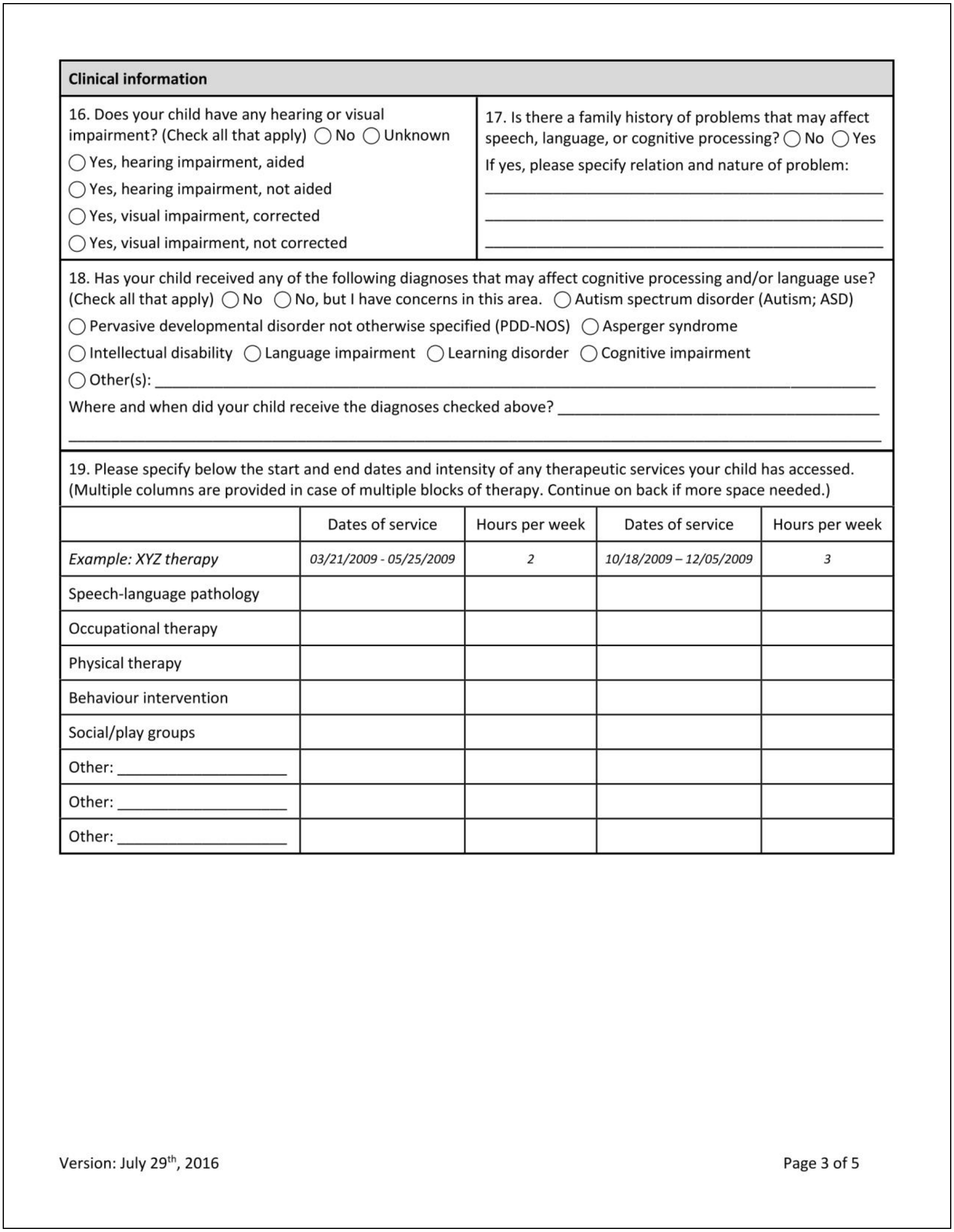

Clinical information

16. Does your child have any hearing or visual impairment? (Check all that apply) ○ No ○ Unknown
○ Yes, hearing impairment, aided
○ Yes, hearing impairment, not aided
○ Yes, visual impairment, corrected
○ Yes, visual impairment, not corrected

17. Is there a family history of problems that may affect speech, language, or cognitive processing? ○ No ○ Yes
If yes, please specify relation and nature of problem:
____
____
____

18. Has your child received any of the following diagnoses that may affect cognitive processing and/or language use? (Check all that apply) ○ No ○ No, but I have concerns in this area. ○ Autism spectrum disorder (Autism; ASD)
○ Pervasive developmental disorder not otherwise specified (PDD-NOS) ○ Asperger syndrome
○ Intellectual disability ○ Language impairment ○ Learning disorder ○ Cognitive impairment
○ Other(s): ____
Where and when did your child receive the diagnoses checked above? ______________________________________
____

19. Please specify below the start and end dates and intensity of any therapeutic services your child has accessed. (Multiple columns are provided in case of multiple blocks of therapy. Continue on back if more space needed.)

	Dates of service	Hours per week	Dates of service	Hours per week
Example: XYZ therapy	*03/21/2009 - 05/25/2009*	*2*	*10/18/2009 – 12/05/2009*	*3*
Speech-language pathology				
Occupational therapy				
Physical therapy				
Behaviour intervention				
Social/play groups				
Other: ____________________				
Other: ____________________				
Other: ____________________				

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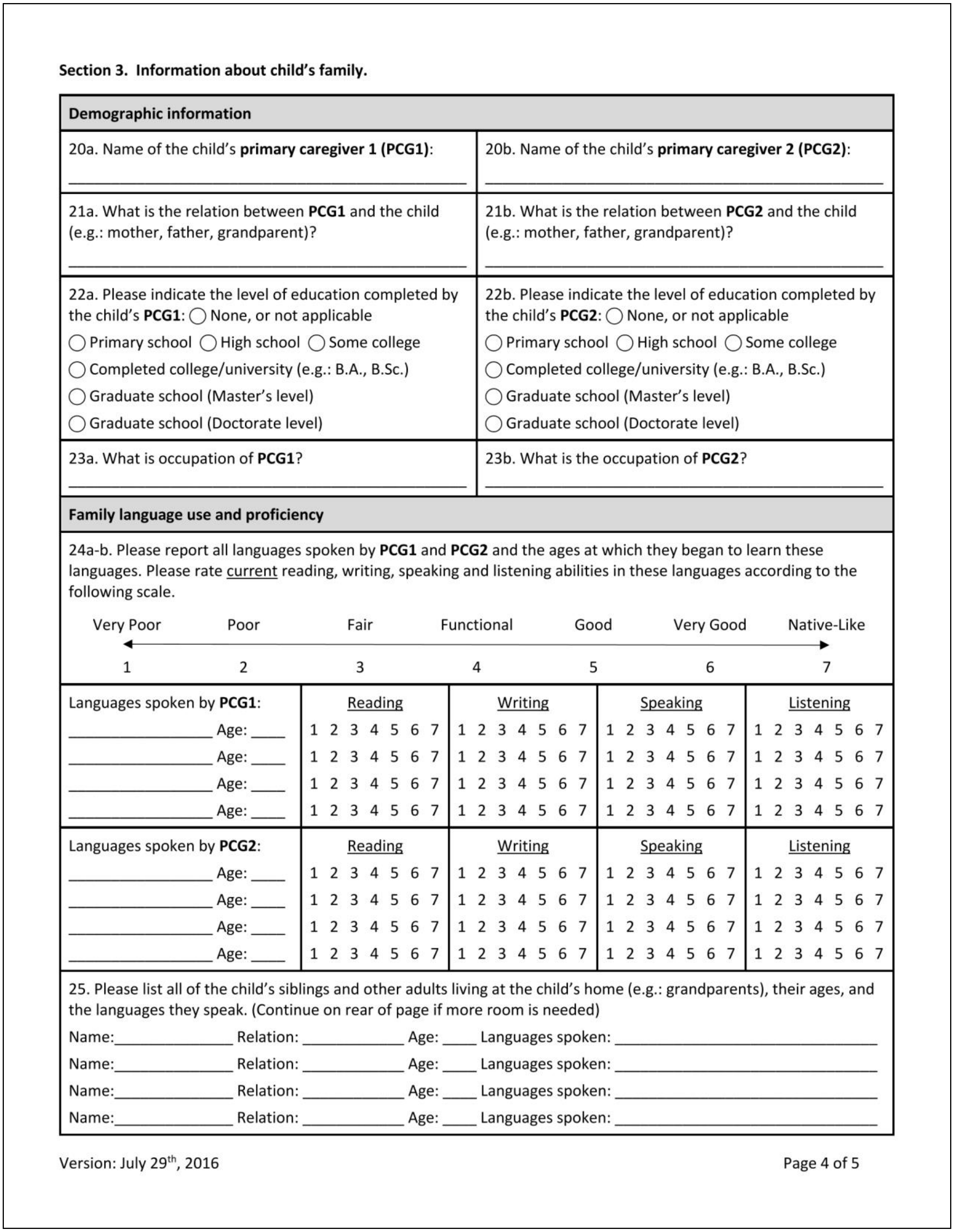

Section 3. Information about child's family.

Demographic information	
20a. Name of the child's **primary caregiver 1 (PCG1)**: ________________________________	20b. Name of the child's **primary caregiver 2 (PCG2)**: ________________________________
21a. What is the relation between **PCG1** and the child (e.g.: mother, father, grandparent)? ________________________________	21b. What is the relation between **PCG2** and the child (e.g.: mother, father, grandparent)? ________________________________
22a. Please indicate the level of education completed by the child's **PCG1**: ○ None, or not applicable ○ Primary school ○ High school ○ Some college ○ Completed college/university (e.g.: B.A., B.Sc.) ○ Graduate school (Master's level) ○ Graduate school (Doctorate level)	22b. Please indicate the level of education completed by the child's **PCG2**: ○ None, or not applicable ○ Primary school ○ High school ○ Some college ○ Completed college/university (e.g.: B.A., B.Sc.) ○ Graduate school (Master's level) ○ Graduate school (Doctorate level)
23a. What is occupation of **PCG1**? ________________________________	23b. What is the occupation of **PCG2**? ________________________________

Family language use and proficiency

24a-b. Please report all languages spoken by **PCG1** and **PCG2** and the ages at which they began to learn these languages. Please rate <u>current</u> reading, writing, speaking and listening abilities in these languages according to the following scale.

Very Poor	Poor	Fair	Functional	Good	Very Good	Native-Like
1	2	3	4	5	6	7

Languages spoken by **PCG1**:	<u>Reading</u>	<u>Writing</u>	<u>Speaking</u>	<u>Listening</u>
______________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
______________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
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Languages spoken by **PCG2**:	<u>Reading</u>	<u>Writing</u>	<u>Speaking</u>	<u>Listening</u>
______________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
______________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
______________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
______________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7

25. Please list all of the child's siblings and other adults living at the child's home (e.g.: grandparents), their ages, and the languages they speak. (Continue on rear of page if more room is needed)

Name:____________ Relation: __________ Age: ____ Languages spoken: ________________________

Name:____________ Relation: __________ Age: ____ Languages spoken: ________________________

Name:____________ Relation: __________ Age: ____ Languages spoken: ________________________

Name:____________ Relation: __________ Age: ____ Languages spoken: ________________________

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Section 4. Your child's language(s).

AAC use

26. Does your child use an alternative or augmented communication (AAC) system to help them communicate (e.g.: PECS, TouchChat, other iPad communication app)? ○ No ○ Yes: ____

If yes, when did your child begin using this system? Please specify an approximate date: ________________________

Language use and proficiency

27. Please report all languages spoken by **your child** and the ages at which they began to learn these languages. Please rate current reading, writing, speaking and listening abilities in these languages according to the following scale. Your child is not expected to have fully developed language skills, so ratings should be relative to their age.

Very Poor (for their age)	Poor (for their age)	Fair (for their age)	Functional (for their age)	Good (for their age)	Very Good (for their age)	Native-Like (for their age)
◄ 1	2	3	4	5	6	7 ►

Languages spoken by your child:	Reading	Writing	Speaking	Listening
_________________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
_________________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
_________________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
_________________ Age: ____	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7

Section 5. A timeline of your child's language exposure and use (interview).

Due to the variable nature of children's language exposure and use, this portion of the questionnaire will be conducted as an interview. During the interview, you will be asked for a detailed history of your child's language exposure (i.e.: the language(s) they hear) and your child's language use (i.e.; the language(s) they speak). If your child uses an augmented or alternative communication (AAC) system, the interview questions will change slightly to reflect your child's mode(s) of communication. The level of detail requested in this interview is needed to ensure that we get a complete picture of your child's language history.

Some important things to think about before the interview include:

- ✓ Language(s) your child heard in the first years of life: Did they hear only one language? More than one?
- ✓ Language(s) your child spoke in the first years of life: Did they use only one language? More than one?
- ✓ Any changes there may have been to your child's language exposure after ASD/other diagnosis.
- ✓ Any periods where your child heard an additional language which they don't typically hear (e.g.: hearing Spanish for a few months when your child is not typically exposed to Spanish).
- ✓ Any periods where your child did not hear a language which they typically hear (e.g.: not hearing Cantonese for a few months when your child is typically exposed to Cantonese).
- ✓ Any strong associations between a particular language and a person and/or environment (e.g.: your child only speaks French at school; only the child's grandparents use Punjabi; your child attends Chinese Sunday school).

Section 6. Anything else?

You know your child better than anyone else. Please comment on anything that was not addressed in this questionnaire that you believe may be important in your child's history of language exposure/use.