WORKING MEMORY AND CONTROLLED ATTENTION IN BILINGUAL CHILDREN WITH AND WITHOUT LANGUAGE IMPAIRMENT

Mahchid Namazi, MSc
School of Communication Sciences & Disorders
McGill University, Montreal

August 2009

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Doctorate of Philosophy

Table of Contents

Manuscript 2

Distraction by Meaningful Competing Speech: A Bilingual or Working Memory Advantage

<u>Manuscript 3</u>

<u>Resisting Interference: A Preliminary Study on the Effects of Bilingualism and Language Impairment</u>

Abstract

This thesis consists of three studies with the general aim of investigating controlled attention and working memory in the visual and auditory modalities in monolingual and bilingual children equated in visual and verbal working memory as well in bilingual children with and without language impairment. The first study attempts a replication of previous research findings showing a bilingual advantage in controlled attention by altering the methodology to equate children on measures of verbal and visual working memory, as well as adequately measuring language knowledge in each of the bilingual child's languages. In the second study, we performed a preliminary investigation of bilingual children's ability to ignore meaningful speech in one language while attending to and processing sentences in the other language. The regular experience with this latter skill has been put forward as the explanation for the bilingual child's domain general advantage in controlled attention. A second general aim of the studies was to explore the relationship between verbal memory and auditory controlled attention, as well as visual memory and visual controlled attention. The third and final study extended the aims of the first two studies to bilingual children with language impairment in comparison to an age- and nonverbal IQ-matched group with similar bilingual exposure. The findings from all three studies confirmed the lack of a bilingual advantage in visual controlled attention. Furthermore, even in children with language impairment, performance was similar to their peers. As for the relationship between working memory and controlled attention, when children were split into high and low visual working memory groups, those with higher spans were more accurate and faster on the visual controlled attention task. In the case of auditory controlled attention, children with higher verbal working memory scores were more accurate than those with lower working memory scores. This study supports the claim made by others that individual differences in working memory contribute to performance on tasks of controlled attention.

Résumé

Cette thèse est constituée de trois articles dont le but général est l'investigation du contrôle de l'attention et de la mémoire de travail dans les modalités visuelle et auditive chez les enfants bilingues et monolingues appariés en mémoire de travail visuelle et auditive ainsi que chez les enfants avec et sans trouble de langage. La première étude vise à répliquer des données antérieures démontrant un avantage cognitif chez les enfants bilingues dans le domaine de l'attention sélective, mais en changeant la méthodologie pour comparer des enfants bilingues et monolingues appariés au niveau de la mémoire de travail visuelle et auditive. De plus, le développement langagier chez tous les enfants a été mesuré de façon approfondie. Le deuxième article est une investigation préliminaire de la capacité des enfants bilingues à faire attention à une tâche auditive-verbale dans une de leurs langues tout en ne pas se laissant distraire par un discours verbal dans la même ou dans l'autre langue. Il a été proposé que l'expérience régulière des enfants bilingues avec une telle alternance entre les deux langues pourrait expliquer l'avantage observé chez les enfants bilingues dans le domaine général du contrôle attentionnel. Un deuxième but général de cette recherche est d'explorer la relation entre la mémoire de travail verbale et

l'attention sélective auditive-verbale ainsi que la mémoire visuelle et l'attention sélective visuelle. Le troisième et dernier article cible les objectifs des deux premières études chez des enfants bilingues présentant une dysphasie en comparaison avec des enfants du même âge, même niveau cognitif non verbal et même degré d'exposition au bilinguisme ayant un développement langagier normal. Les résultats des trois articles mènent tous à la conclusion qu'il n'existe pas un avantage cognitif dans l'attention sélective visuelle chez les enfants bilingues. Deuxièmement, Les enfants bilingues ayant une dysphasie ont performé pareillement à leurs pairs. Il ressort des données une relation entre la mémoire de travail et l'attention sélective – quand les enfants ont été divisés en deux groupes selon leurs scores en mémoire de travail, les enfants avec des scores élevés avaient aussi les meilleurs scores au test de l'attention sélective visuelle. Il en a été de même pour l'attention sélective auditive. Cette étude soutient donc la proposition faite par d'autres que la variation individuelle dans la mémoire de travail contribue à la performance dans les tâches d'attention sélective.

.

Acknowledgments

The people who accompanied me on this journey are few in number, however their support, advice, and encouragement were essential to the completion of this thesis and I will remain forever indebted to them. I would like to begin by thanking Dr. Shari Baum who went above and beyond the call of duty on numerous occasions. Her dedication and attention to students even those not directly under her supervision are admirable and humbling. I am particularly grateful for her attention to detail and her sage advice - thank you Shari. Dr. Linda Polka's reading of the manuscripts is greatly appreciated as she brought a unique and valuable perspective. I also want to extend a warm thank you to Ms. Nancy Fung, Ms. Marie-Helene Vanier and the other research assistants in Dr. Elin Thordardottir`s laboratory without whom the data collection for this thesis would have been virtually impossible. To my PhD colleagues and friends, in particular Ms. Pi-Yu Chiang and Dr. Nathalie Bélanger who understood well what I was living, I thank you for your support and friendship – it got me through the rough patches and enabled me to celebrate every little achievement.

I extend a warm and grateful thank you to my dear friend and confidante, Joni, who was always a phone call away when I needed to chat and she cheered me on as only she knows how to do. She was instrumental in my conviction to embark on a PhD as well as to complete it. I would not have wanted to make it this far without Mahyar, my husband and best friend, whose immense sacrifice turned a mere dream into reality. The odds were stacked against this venture but his unwavering support and belief that I could achieve this goal gave me the daily strength I needed to complete this journey successfully. To my daughter, Lili, qui est ma raison d'être and was my inspiration during the second and in many ways most challenging half of this journey thank you for understanding why mommy was not always around as much as I wanted to be and as often as you needed me to be – always remember, I succeeded *because* you came into my life.

And of course, last but certainly not least, I owe immense gratitude to my mentor and advisor, Dr. Elin Thordardottir mostly because she always understood that real life presented many challenges while I tried to finish my PhD. I experienced mostly ups but also a few downs during this process and Elin, you always managed to convince me not to take myself too seriously. As for the ups (Lyon 2005, San Diego 2005, Arizona 2005, Bangor 2008 to mention but a few.), it was fun to celebrate them with you - thank you for your gentle encouragement, guidance, support, and patience which have made me a more rigorous, capable, and confident researcher.

Finally, without the children who participated in this process, none of this would have been feasible – their parents agreed to their participation because they believed that my research would one day make a small contribution to improving our understanding of language development and disorder in bilingual children – I hope I can make this happen for them.

Funding and support

The collection and analysis of all data reported on in this thesis were funded by a standard research grant from SSHRC (The Social Sciences and Humanities Research Council of Canada) awarded to Elin Thordardottir. The candidate's doctoral studies were also supported by a post-graduate student scholarship awarded to Mahchid Namazi by the National Science Engineering and Research Council of Canada and, in the later stages, by funding support from the Canadian Federation for University women and McGill university in the form of the Faculty of Medicine scholarship and the McGill majors.

Contribution of authors

For the three manuscripts that make up this thesis, the research design, hypothesis formulation, development of new stimuli required for this study, statistical analysis, interpretation of results, and manuscript writing were the primary responsibility of Mahchid Namazi. Recruitment and testing of participants was the responsibility of Mahchid Namazi and Elin Thordardottir and her research assistants. Dr. Elin Thordardottir provided guidance in all aspects of the undertaking.

General Introduction

The intellectual consequences of childhood bilingualism have been debated since at least the early 20th century. Leopold (1939-1949) was one of the first to detail the favorable effects of bilingualism on mental development in a child brought up in a one-parent one-language, other-parent other language home environment. Vygotsky (1962) concluded that bilingual children understood the arbitrary nature of form-meaning relationships earlier than monolingual children because he observed that the bilingual child more easily solved the Piagetian 'sun-moon' problem. Findings such as those of Leopold and Vygotsky inspired many years of research into the positive consequences of bilingualism on not only metalinguistic awareness but other areas of cognitive development. One important example of such research is that of Peal and Lambert's (1962) precedent-setting study which led to a wave of research highlighting the positive consequences of bilingualism. These researchers made the strong claim that bilingual children surpassed monolinguals on *all* measures of verbal and nonverbal intelligence. One of the major interpretive difficulties of this study was that because the advantages were only observed in the balanced bilinguals (those who spoke English and French equally well), it was not possible to rule out the explanation that children who became 'balanced' bilinguals were the very same ones who started out with better cognitive abilities. In fact, as Peal and Lambert themselves admit, the frequency distribution of the bilinguals' scores on the nonverbal tests was negatively skewed; that is, although some children of "low intelligence" became bilingual, most of the bilinguals scored higher on the intelligence tests. Peal and Lambert's explanation for the better performance of the bilingual children was that they were more flexible thinkers because speaking two different languages involves having two symbols for many objects, thus allowing them to conceptualize the world in terms of *general* properties without over-reliance on linguistic symbols. An alternative explanation given was that bilinguals have developed more flexibility in thinking due to having to regularly switch from one language to another. The research stage had been set for the exploration of the relationship between bilingualism and cognition culminating in the late 20th century by research from Bialystok and colleagues showing advantages in controlled attention in bilingual children as compared to their monolingual peers (Bialystok, 1999; Bialystok & Martin, 2004; Bialystok, Martin, Viswanathan, 2005; Bialystok & Senman, 2004; Bialystok & Shapero, 2005).

Statement of Purpose

The purpose of this project was to investigate the relationship between controlled attention and working memory in the visual-nonverbal as well as auditory-verbal domains in 5-year old bilingual children with and without Specific Language Impairment (SLI). Controlled attention (alternatively called inhibitory control, executive control, attentional control, or executive attention in the relevant research literature) is the ability to direct attention to specific aspects of a stimulus field or mental representation during *real-time* tasks and becomes particularly important when there is conflict in the form of irrelevant information. Recent research has shown that balanced bilingual children who use both languages on a regular basis excel at tasks that require visually controlled attention when compared to their monolingual age-matched peers (e.g. Bialystok, 1999). It has also been shown that controlled attention plays an important role in language development; this is highlighted by Nation, Marshall, and Altmann (2003), who found a positive relationship between the ability to suppress irrelevant information and real-time sentence comprehension in children. Children assessed as good language comprehenders were more successful at a test of controlled attention relative to poor comprehenders of the same age. The ability to control attention has also been investigated in children with developmental language disorders as well as children with high functioning autism. For example, Liss et al. (2001) found that the ability to control attention distinguished children with language disorder from their typically developing IQ matched peers. In typically developing children, controlled attention has been correlated with language ability in monolinguals at varying linguistic levels (Wolfe & Bell 2004), with Theory of Mind abilities (Hughes 1998), and with mathematical abilities (Epsy, McDiarmid, Cwik, Stalets, Hamby, & Senn 2004). Therefore, controlled attention is a cognitive construct that seems to be central in achieving success on a variety of different cognitive tasks.

Controlled Attention and Bilingualism

In typically developing bilingual children, it has been shown that they outperform their age-matched monolingual peers on tasks involving controlled attention (Bialystok, 1999). For example, Bialystok (1999) investigated controlled attention in Chinese/English bilingual and English monolingual 4 and 5-year old children This study was one of the first to demonstrate an advantage in controlled attention in bilingual children on a nonverbal task. This controlled attention advantage has now been replicated in infants (Kovacs & Mehler, 2009), children and adults (Bialystok & Martin, 2004; Bialystok, Martin, Viswanathan, 2005; Bialystok & Senman, 2004; Bialystok & Shapero, 2005) but is not uncontroversial (Morton & Harper, 2007 & 2009) due to certain methodological limitations. First, the only measure of language aptitude taken to measure language proficiency has traditionally been that of receptive vocabulary in English; language proficiency in the other language has not been documented. It is now widely accepted that assessing a bilingual child in one language fails to cover the full extent of the child's linguistic proficiency (e.g. Elin Thordardottir, Rothenberg, Rivard, & Naves, 2006; Umbel, Pearson, Fernandez, & Oller, 1992). Furthermore, research overwhelmingly supports the fact that bilingual children can sometimes score lower on measures of language when assessed in only one of their languages (e.g. Elin Thordardottir et al., 2006; Umbel et al., 1992). Elin Thordardottir et al. (2006), for example, found that 3-year old bilingual children scored lower than monolinguals on all measures except receptive vocabulary, and in a follow-up on 5-year olds (Elin Thordardottir, 2008), children with certain exposure patterns scored similar to monolinguals on basically all measures, although some continued to score lower than monolinguals. Related to this latter issue is that visual short-term memory tasks have often been used to match children on nonverbal cognitive abilities. A substantial body of research has documented that in children, auditory-verbal working memory skills, and not visual short-term memory, constrain the acquisition of a variety of complex abilities such as language and reading abilities, arithmetic skills, and vocabulary acquisition (Gathercole & Pickering, 2000). The controlled attention tasks used in the bilingual advantage literature are complex ones for young children because they require understanding, recalling, and implementing rules, inhibiting a response, as well as ignoring perceptual distractions. Therefore, performance on these types of tasks may not simply depend on controlled attention but may very well be mediated by working memory abilities.

The Role of Working Memory

Engle, Kane, and Tuholski (1999) proposed a model of working memory (WM) that clearly specifies the role of controlled attention, which is the cognitive construct currently at the centre of the bilingual advantage literature. This model details a more continuous relationship between WM, short-term memory (STM) and controlled attention. In this model, the underlying WM construct is viewed as continuous, ranging from individuals who have *more* attentional resources (or can regulate resources more effectively) to those who have *fewer* resources (or who regulate less well) (Barrett, Tugade, & Engle, 2004). Engle and colleagues have shown that individual differences in WM capacity may actually determine the ability to control attention. For example, Rosen and Engle (1998) demonstrated that the ability to suppress intrusive thoughts and behaviours, a skill requiring controlled attention, is highly dependent on an individual's WM capacity. Engle (2002) also showed that controlled attention varied as a function of WM capacity; that is, greater WM capacity may mean greater ability to use attention to avoid distraction and that dealing with the effects of interference (that is, controlled attention) is one of the primary functions of working memory.

Working memory has also been implicated in second language acquisition (Service, 1992); the ability to represent unfamiliar phonological material in working memory was at the core of the acquisition of new vocabulary items in a foreign-language in a group of nine-year old children. In another line of research, controlled attention has been used to explain enhanced working memory (e.g. Engle, Kane, & Tuholski, 1999) and language comprehension (Hughes, 1998) abilities. Daneman and Merikle's (1996) meta-review found that working memory measures were better predictors of global and specific language skills than simply short-term memory measures that tap only storage capacity. Finally, children with language impairment have been shown to have reduced working memory capacities compared to their language-matched and age-matched peers (e.g. Ellis Weismer, Evans, & Hesketh, 1999). These findings about working memory across different populations, both typical and those with delays, clearly highlight the close relationship between working memory and language development. Therefore, the importance of measuring the working memory abilities of bilingual and monolingual children who are being compared on complex problem-solving tasks of controlled attention is highlighted.

Controlled attention in the auditory-verbal modality

One of the most intriguing things about the finding that bilingual children perform better than their monolingual peers on tasks of controlled attention is that this benefit is observed in the visual-nonverbal modality. It is unclear how learning two languages, a seemingly auditory-verbal activity, should lead to an advantage in the visual domain. The recent explanation offered (e.g. Bialystok, 1999) is not that unlike the one offered by Peal & Lambert (1952) in that the continuous switching between two languages and thus the act of ignoring one language while attending to the other over time translates to domain-general advantages in controlled attention. On the other hand, in the auditory modality, some research shows that bilingual children have more difficulty than monolingual peers in comprehending speech in the context of background noise (Kohnert, Sabur, and Shaw, 2005). It is difficult to reconcile these two lines of research; on the one hand, bilingual children are said to excel at nonverbal tasks of controlled attention because they can effectively ignore one language and attend to the other while alternatively they have more trouble perceiving speech in the background noise. What remains to be clarified is how bilingual children perform in relation to their monolingual peers on an auditory verbal task where they need to ignore one language while attending to the other. That is, how do they perform on the very kind of task which is reported to lead to the observed advantage in controlled attention in the visual modality? We refer to this construct as the ability to control attention in the auditory-verbal modality.

Nation, Marshall, and Altmann (2003) found that there is a positive relationship between the ability to suppress irrelevant information and real-time sentence comprehension in children. Children assessed as good language comprehenders were more successful on a test of controlled attention relative to poor comprehenders of the same age. In typically developing children, controlled attention has been correlated with language ability in monolinguals at varying linguistic levels (Wolfe & Bell 2004). Sentence comprehension has also been linked to working memory abilities as well as the ability to suppress irrelevant information (controlled attention) in both typical children and children with language disorders (e.g. Nation et al, 2003; Montgomery, 2000a, 2002, 2003). Engle et al. (1999) also highlighted the important relationship between WM capacity and language abilities. For example, in two longitudinal studies with children, WM measures for each year predicted the subsequent year's comprehension scores. Adams, Bourke, & Willis (1999) found that spoken language comprehension was associated with both listening span and phonological memory but not visuospatial memory, in a group of five-year old children. Therefore, studying the relationship between visual memory, verbal memory, and controlled attention may lead to alternative explanations for the observed advantage in bilingual children.

Specific Language Impairment

Children with SLI display deficits in language function with age-appropriate scores on non-verbal intelligence tests, normal peripheral hearing, and normal social-emotional development in the absence of evidence of frank neurological dysfunction. Information processing accounts in monolingual children with SLI have appealed to working memory limitations to explain the observed language deficits. Both phonological short-term memory and verbal working memory deficits have been implicated. The phonological memory deficit of SLI is based on the model proposed by Baddeley (2003) and

Gathercole and Baddeley (1990), where the language difficulties are attributed to deficits in phonological memory as measured by repetition of non-words varying in length from one to five syllables. Repetition accuracy begins to decrease at three syllables and beyond in typically developing children; the greater the child's phonological memory, the better accuracy he will have for longer items (Montgomery 2003). Gathercole and Baddeley (1990) found that children with SLI had more difficulty repeating nonsense words and recalling lists of real words than their mental age-matched and language age-matched controls. Gathercole and Baddeley (1993) have further proposed that these deficits in phonological memory may negatively affect the comprehension and processing of grammar. Evidence in support of Gathercole and Baddeley's hypothesis (1990, 1993) has uncovered limitations in nonsense word repetition in children with SLI, as well as in children with learning disabilities (Gillam, Cowan, and Day 1995; Kamhi and Catts 1986; Kamhi, Catts, Mauer, Apel and Gentry 1988; James, van Steenbrugge, and Chiveralls 1994).

The verbal working memory account of SLI, based on the model of working memory proposed by Daneman and Carpenter (1980) utilizes a developmentally appropriate version of their sentence span task, called the Competing Language Processing Task (CLPT) developed for younger children (Gaulin and Campbell, 1994). Gaulin and Campbell (1994) found a positive association between word recall on the CLPT and receptive-language abilities. It has also been shown that children with SLI have more trouble with language tasks presented under 'stressful' processing conditions (at fast rates, for example) due to the difficulty of managing both the storage and processing functions of verbal working memory (Ellis Weismer, 1996). Finally, further evidence for this account comes from Montgomery (2000a), who showed that children with SLI comprehended fewer of the longer sentences relative to their language-matched controls. The above review demonstrates that children with SLI have deficits in both phonological short-term memory, as well as verbal working memory. However the results on the correlation of these two kinds of working memory with the observed language deficits remains varied and yields conflicting findings.

There is, to date, minimal data on how phonological memory and verbal working memory measure up in bilingual children with SLI. Studies looking at SLI and bilingualism tend to make three-way comparisons between monolingual children with SLI, typically developing monolinguals, and typically developing bilinguals (e.g. Kohnert, Windsor, & Yim, 2006). When bilingual children with SLI have been compared to monolingual peers with SLI, the focus of investigation has been on morphosyntax in French-English (e.g. Paradis, Crago, Genesee, Rice, 2003) as well as Spanish-English bilinguals (Jacobson & Schwartz, 2002). There is recent evidence that phonological memory is also impaired in bilingual children with SLI, who showed lower than average scores in comparison to typically developing monolingual children (Girbau & Schwartz, 2008). In my literature review, I was unable to locate any study that has looked at the relationship between working memory and controlled attention in bilingual children with SLI compared to bilingual children without SLI. Furthermore, there are as yet no published findings on the nonlinguistic abilities of bilingual children with SLI. Since much of the research with monolingual children with SLI has found deficits in working memory and there is some evidence that these children also have nonverbal processing deficits, it seems important to investigate the interaction of these abilities in bilingual children with SLI also.

Putting it all together: General Outline and Objectives

As reviewed above, some research with bilingual children, children with language impairment, autism, and other developmental disorders has shown that there are differences in controlled attention relative to the relevant matched peer group. In bilingual children, controlled attention has been measured at the exclusion of working memory, which may also account for the observed differences. In the studies on working memory deficits in children with SLI, the potential contribution of controlled attention has not been considered – a factor which may have contributed to the diverse set of findings. Finally, there is now some evidence that typically developing bilingual children perform better on tests of controlled attention when compared to their monolingual peers.

In this series of three studies, I will explore the relationship between working memory (WM) and controlled attention (CA) in the visual and auditory modalities in 5-year old bilingual children with and without SLI. In the first study, I will attempt to replicate the findings of a bilingual advantage in controlled attention on the Simon task by altering the methodology to include thorough measures of verbal and nonverbal memory, as well as language aptitude. Children have also been matched on age, nonverbal IQ, and SES. Language abilities in both languages will be measured in order to account for any potential differences between groups. The bilingual children will be compared to two groups of monolingual children (in each language). Furthermore, I included measures of visual and verbal short-term and working memory in order to determine whether there is a relationship with performance on controlled attention as measured by the Simon task. In the second study, I will investigate the relationship between working memory and controlled attention in the auditory-verbal modality. The same group of children as in study one were compared on a sentence comprehension task in the context of meaningful speech used as a distracter. The purpose of this task was two-fold; first I wanted to determine how bilingual children perform relative to their monolingual peers on a task that mimics the bilingual experience, and second, I wanted to know the relationship between performance on such a task and working memory. In the third study, I investigated the same questions as in study one and two but this time in bilingual children with SLI as compared to a matched group without SLI.

The first study addresses the following general questions:

1. How do typically developing bilingual children with similar verbal and nonverbal abilities as their age-matched monolingual peers perform on a visual measure of controlled attention?
2. What is the relationship between nonverbal-visual working memory and controlled attention in these groups of children?

In study two, we addressed the following general questions:

3. How do typically developing bilingual children with similar verbal and nonverbal abilities as their age-matched monolingual peers perform an

auditory measure of controlled attention that simulates the bilingual experience?

4. What is the relationship between verbal working and short-term memory tasks with controlled attention in the auditory-verbal domain in these groups of children?

Study three expands on the first two studies by investigating the same issues in bilingual children with SLI; the questions are as follows:

1. How do bilingual children with SLI compare to their age- and level of bilingualism- matched peers on visual and auditory controlled attention?
2. What is the relationship between visual and verbal working memory tasks with controlled attention in the auditory-verbal and visual-nonverbal domains in these children?

The first study makes a novel contribution to the issue of the bilingual advantage by including measures of verbal and visual working memory, as well as thorough language testing in each of the bilingual children's languages. Furthermore, it includes two monolingual comparison groups, which has not been the case in the previous research on the bilingual advantage in controlled attention. The second study is novel in its own right as it is a first attempt to simulate the real-world experience of bilingual children in ignoring one language while attending to the relevant one. Practice in this very skill has been offered as the explanation for a bilingual advantage in visual controlled attention. It is a preliminary investigation of what we refer to as auditory controlled attention in balanced bilingual children as compared to their monolingual peers in each language. Finally, the third study is the first of its kind to explore the questions addressed in the first and second study in bilingual children with and without SLI. It adds to the limited body of research about SLI in bilingual children and improves our understanding of both the verbal and nonverbal abilities in this group of children.

<u>**A working memory, not bilingual advantage, in controlled attention**</u>

Mahchid Namazi and Elin Thordardottir

Abstract

In this first of three studies, we explored the relationship between memory and visually controlled attention in young bilingual and monolingual children. Previous research has shown that balanced bilingual children outperform monolinguals in controlled attention (Bialystok, 1999). However, it is unclear whether this advantage is truly associated with bilingualism or whether potential working memory and hence language differences between the bilinguals and monolinguals led to the observed effects. Therefore our aim was to examine whether bilingual and monolingual children differ on a visual measure of controlled attention after potential differences in verbal and visual working memory had been accounted for. A second aim was to look at the relationship between visually controlled attention and visual working memory. Fifteen French monolingual children, 15 English monolingual children, and 15 early simultaneous French-English bilingual children completed verbal short-term memory, verbal working memory, visual working memory, and visual controlled attention tasks. Detailed information regarding language exposure was collected and children's abilities in each language were evaluated. A bilingual advantage in visual controlled attention was not found; monolingual and bilingual children were equally successful in ignoring the irrelevant perceptual distraction in the Simon task. Furthermore, visual working memory correlated significantly with the visual controlled attention task. The results

indicate that when bilingual and monolingual children have similar working memory and language abilities, they also perform similarly on a task of controlled attention and that visual working memory as measured by the Pattern Recall task partially determines success on the Simon task.

Introduction

In recent years, research has indicated that fluent bilingual children excel at nonverbal tasks requiring controlled attention when compared to their monolingual peers (e.g. Bialystok, 1999; Bialystok & Martin, 2004; Bialystok, Martin, Viswanathan, 2005; Bialystok & Senman, 2004; Bialystok & Shapero, 2005). Controlled Attention (CA) has been broadly defined as the ability to direct attention to specific aspects of a stimulus field or mental representation during *real-time* problem solving and becomes particularly important when there is conflict in the form of irrelevant information. A bilingual advantage in CA has been observed across the lifespan on a variety of different tasks (Bialystok, 1999; Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok & Martin, 2004; Bialystok & Senman, 2004; Bialystok & Shapero, 2005). The advantage has been said to arise from the bilingual's continual practise with ignoring the non-relevant language in order to communicate effectively in the relevant one. Over time, this continual practice in the linguistic domain generalizes to cognitive processes that are primarily non-linguistic in nature.

A prototypical nonverbal task of controlled attention used in this type of research is the Simon task, in which participants are alternatively presented with a shape in two different colours appearing randomly on either the left or right side of a computer screen. The participant's task is to press the button corresponding to the appropriate colour as soon as the shape is presented. On congruent trials, the button to be pressed and the corresponding shape are on the same side, while on incongruent trials, they are on opposite sides. It is the competition between the irrelevant location cues on incongruent trials and the colour cue that reportedly place a particular demand on controlled attention. Martin-Rhee and Bialystok (2008) compared the performance of 5-year old bilingual and monolingual children on the Simon task. French/English bilingual children matched on digit span (verbal short-term memory) in English had faster reaction times than their monolingual peers on the Simon Task on both congruent and incongruent trials. Similar results have been replicated in older adults (e.g. Bialystok, Craik, Klein, & Viswanathan, 2004) and in other groups of preschool-age bilingual children (e.g. Bialystok, 2006; Martin-Rhee & Bialystok, 2008).

The proposed explanation for the observed bilingual advantage on the Simon task is that it arises from continued practice with attending to one language while ignoring the other a skill that enhances controlled attention (Green, 1998). It is, however, possible that differences in monolingual and bilingual children's controlled attention derive in part from differences in working memory (WM) abilities. The role of working memory is important for two reasons. First, since working memory is the storage and processing of information during the performance of complex cognitive tasks, it necessitates focusing attention and ignoring irrelevant information; that is, it is highly related to controlled attention (Engle, Kane, & Tuholski, 1999; Miyake & Shah, 1999). Second, since one of the major functions of working memory is the retention and processing of verbal information, and working memory capacity is highly correlated with first and second language abilities, it is reasonable to infer that working memory serves language acquisition (Blake, Austin, Cannon, Lisus, & Vaughan, 1994; Ellis &

Sinclair, 1996; Gathercole & Baddeley, 1989; Gathercole, Service, Hitch, Adams, & Martin, 1999; Miyake & Shah, 1999; Service, 1992).

The Simon task makes demands on WM. It does not simply require ignoring irrelevant location cues on incongruent trials; the participant also must remember two rules in a complex conditional linguistic frame (e.g. if it's red, press the red button; if it's blue, press the blue button) *while* suppressing the tendency to press the wrong button in non-corresponding trials. It is the combination of remembering what to do and doing it in the face of distraction that recruits working memory processes. Gerstadt, Hong, and Diamond (1994) suggested that performance on a Stroop-like day-night task in 3.5 to 7 year old children did not require controlled attention exclusively but controlling attention in combination with tolerating the working memory load of holding multiple rules in mind. Controlled attention can also be viewed as a suppression resource that prevents entry or maintenance of irrelevant information in WM. Therefore, it is possible that a high working memory capacity can more easily accommodate suppression of task-irrelevant information (Roncandin, Pascual-Leone, Rich, & Dennis, 2007). Furthermore, measures of verbal WM capacity, such as the listening span, reflect some fundamental ability related to higher-level cognition because they reliably predict performance on a wide variety of real-world and complex cognitive tasks such as reading comprehension, language comprehension, learning to spell, following directions, vocabulary learning, note-taking, writing, reasoning, and complex learning (Engle, 2002).

Engle, Kane, and Tuholski (1999) proposed a model of WM that clearly specifies the role of controlled attention, which is the cognitive construct currently at the centre of the bilingual advantage literature. This model details a more continuous relationship between WM, short-term memory (STM) and controlled attention. In this model, the underlying WM construct is viewed as continuous, ranging from individuals who have *more* attentional resources (or can regulate resources more effectively) to those who have *fewer* resources (or who regulate less well) (Barrett, Tugade, & Engle, 2004). Engle and colleagues have shown that individual differences in WM capacity may actually determine the ability to control attention. For example, Rosen and Engle (1998) demonstrated that the ability to suppress intrusive thoughts and behaviours, a skill requiring controlled attention, is highly dependent on an individual's WM capacity. Engle (2002) also showed that controlled attention varied as a function of WM capacity; that is, greater WM capacity may mean greater ability to use attention to avoid distraction and that dealing with the effects of interference (that is, controlled attention) is one of the primary functions of working memory. Rosen and Engle (1997) showed that in a category fluency test, high span individuals generated more animal names than low span individuals. This task requires controlled attention to prevent repeating items that have been mentioned earlier in the list.

The evidence reviewed demonstrates that WM and controlled attention are highly related constructs. In fact, scores on a series of WM tasks at age 3.5 predicted accuracy on a test of controlled attention 2 years later (Engle et al., 1999). Therefore, any finding of an advantage in controlled attention would be far more convincing if working memory were controlled for. If the Engle model of working memory and controlled attention is accurate, then irrespective of bilingualism, children with higher working memory capacities should do better on tests of controlled attention.

A second reason why controlling for WM is particularly important in studies on bilingual children is that strong associations between verbal working memory and language development have been documented for many years (Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Ellis & Sinclair, 1996; Gathercole & Pickering, 2000; Service, 1992). More than 20 years ago, Daneman and Carpenter demonstrated that individual differences in language performance mediate individual differences in verbal working memory. Furthermore, a substantial body of research has documented that in children, working memory constrains the acquisition of a variety of complex abilities such as: language and reading abilities, arithmetic skills, and vocabulary acquisition (Gathercole & Pickering, 2000). Daneman and Merikle (1996) reviewed 77 independent studies spanning more than 50 years of research and found that measures that combined the *storage* and *processing* capacity of working memory together were better predictors of global and specific language comprehension skills than those tapping only storage capacity. Also, some research has shown that WM capacity is highly correlated with second language abilities (Ellis & Sinclair, 1996; Service, 1992), a finding which is highly relevant in the case of participants in the bilingual advantage literature who were sequential bilinguals--that is, those who learned English after the first language was well established (e.g. Bialystok &

Martin, 2004). Finally, one longitudinal study with children between the ages of 3.5 to 5.5 measured abilities on a series of WM tasks as well as a listening comprehension task (Engle et al., 1999). This study showed that the memory measures for each year predicted the subsequent year's comprehension scores, whereas the converse was not true.

Given the above discussion showing a strong and consistent relationship between working memory and other complex cognitive abilities, the measurement of working memory becomes particularly relevant since, in studies on the Simon task, the language abilities of bilingual participants have not been objectively and thoroughly measured in each language (e.g. Goetz, 2003; Bialystok & Senman, 2004; Bialystok, Martin, & Viswanathan, 2005). Furthermore, bilingual children's language skills have been compared to a monolingual English comparison group. Given that in many cases the children were sequential bilinguals for whom English was their second language, this procedure may have grossly under-estimated the language and working memory capacities of the bilingual group. It is now widely accepted that assessing a bilingual child in one language fails to cover the full extent of the child's linguistic proficiency (Elin Thordardottir, Rothenberg, Rivard & Naves, 2006; Elin Thordardottir, 2005; Oller & Pearson, 2007). For example, Elin Thordardottir, Rothenberg, Rivard, and Naves (2006) found that when typically developing bilingual children's English scores were compared to those of monolingual English-speaking age peers, the bilingual children performed significantly less well on all measures (expressive and receptive measures of syntax) *except* receptive vocabulary (as measured by the PPVT). Furthermore, differences were found in how the bilingual children's scores compared to each of the monolingual groups. This study highlights the fact that depending on the language of testing, bilingual children will look like they have different or similar language abilities to their monolingual peers; it further shows that a receptive vocabulary measure may not be the best indicator of a child's language abilities in a particular language. Furthermore, a number of studies have shown that the difference in language scores between monolingual and bilingual children is related to the children's *relative* amount of exposure to the two languages; amount of exposure has not been documented thoroughly in the bilingual advantage literature (Elin Thordardottir, 2008; Oller, Pearson, Cobo-Lewis, 2007). Verbal WM measures, as well, must be collected in both languages. Much of the research on the bilingual advantage has included a simple measure of digit span in one language to equate children on short term memory abilities. This is problematic for at least two reasons. First, digit span has been shown to differ significantly across different languages (Ardila, 2003; Ardila, Rosselli, Ostrosky-Solis, Marcos, Granda, & Soto, 2000; Chincotta & Underwood, 1997). Second, there is evidence that STM and WM are different cognitive constructs and that each makes a contribution to verbal abilities, such that word span correlates with verbal abilities, whereas digit span does not (Cantor, Engle, & Hamilton, 1991). Therefore, it is very possible that bilingual children's digit span was actually under-estimated by measuring it only in English and it did not give a true picture of their verbal memory abilities either.

Another important factor that needs mention, although it is not central to this study, is socio-economic status (SES), which has not been adequately measured in the bilingual advantage literature. Children are recruited from similar geographical areas and assumed to have parents who make similar incomes, however there is no information collected on parent education. The relationship between SES and nonverbal and verbal development has been well documented (Cummins, 2004; Hoff, 2003; Walker, Greenwood, Hart, & Carta, 1994) and this relationship varies according to the context in which the language is spoken. A recent study which attempted to replicate the findings of a bilingual advantage in controlled attention on the Simon task while equating bilingual and monolingual children on ethnicity and SES, in fact, found that the French/English bilinguals and English monolinguals performed similarly on the Simon Task (Morton & Harper, 2007).

The current study

The purpose of the current study was to explore the relationship between verbal working memory, visual working memory, and controlled attention (CA) in 5-year old bilingual and monolingual children. In order to minimize differences in language abilities, the bilingual children formed a homogeneous group of simultaneous fluent bilingual children having received approximately equal amounts of exposure to both languages. Detailed information on language exposure including amount, length, context, and age of acquisition was collected. We also set out to match children a priori on measures of nonverbal cognition, SES, verbal short term memory, and age. We included detailed measures of language abilities so as to be able to account for any potential relationship between experimental measures and scores on language measures. The specific questions we addressed in this study were:

Is there a bilingual advantage in typically developing early simultaneous bilingual children as compared to their monolingual peers?

What is the relationship between visual working memory and a nonverbal test of controlled attention in the visual domain?

Do differences in working memory capacity account for differences in performance on a test of controlled attention in the visual modality?

We predicted that, by considering the role that verbal and visual working memory as well as language abilities play in performance on a task of controlled attention, the bilingual and monolingual children would perform similarly on the Simon Task. We further predicted that there would be a strong relationship between performance on the visual working memory task and a test of controlled attention in the visual modality.

Methods

Participants

Forty-five children participated in the study, divided into three groups of 15 French monolinguals (mean age of 59.4 months, SD 4.9 months, range 52 to 69), 15 English monolinguals (mean age 59.5 months, SD 4.4 months, range 50 to 66 months), and 15 French-English simultaneous bilinguals (mean age 58.7 months, SD 4.2 months, range 53 to 66 months). All children were normally developing with no concerns regarding any area of development, as reported by parents. A hearing screening at 10 dB HL under earphones at octave frequencies from 500 to 4000 Hz was administered to all children. The test was not conducted in a sound-proof booth; therefore reliable results could not be obtained at 500 Hz for some children. Children were matched group-wise on age ($F(2,42) = 0.18$, $p = .84$), nonverbal IQ ($F(2,41) = 0.14$, $p = .87$) using the Leiter International Peformance Scale-Revised (Roid & Miller, 1997), and maternal education (a proxy for SES) ($F(2,42) = 2.65$, $p = .08$). Children were recruited from local preschools and daycares in the greater Montreal area; some of the children in the English monolingual group were recruited and tested in Vancouver, by the first author. Patterns of amount, length, and age of exposure to each language and relative proficiency in French and English were verified by language testing and parent report.

Following Elin Thordardottir et al. (2006), all parents answered a detailed questionnaire on their children's language exposure (including context, amount, length, and age of exposure), parent education, birth order, medical history, and general development. Bilingualism was operationalized as exposure to French and English in meaningful interactive communicative contexts. To be placed in the bilingual group, children had to have been exposed to 40-60% of English and French from before the age of 3 with no exposure to any other language. The majority of children in the bilingual group were exposed to both French and English from before the age of 12 months. To be included in the monolingual group, children were required to have been exposed to French or English consistently from birth with no or minimal exposure (less than 5 hours per week) to a second language.

Children who met criteria as outlined above for inclusion in the bilingual or monolingual groups were seen for further testing All children completed a forward digit span test in English, French, or both (if bilingual), as well as the pattern recall test of visuospatial memory. Children's verbal abilities were tested in the appropriate language/s. In French, the Nouvelles épreuves pour l'examen du langage (NEEL) (Chevrie-Muller & Plaza, 2001) and the Echelle de vocabulaires en images Peabody (EVIP) (Dunn, Thériault-Whalen & Dunn, 1993) were used, while in English, the Clinical Evaluation of Language Fundamentals-Preschool Second Edition (CELF-P2) (Semel, Wiig, & Secord, 2003) and the Peabody Picture Vocabulary Test- Revised (PPVT-III) (Dunn & Dunn, 1997) were used. These tests were given in order to get comprehensive measures of the children's verbal abilities. The EVIP and PPVT-III are standardized tests of receptive vocabulary in French and English, respectively. The NEEL subtests assess receptive and expressive vocabulary, grammar, and morphosyntax in French, while the CELF-P2 evaluates these parameters in English.

The task of matching bilingual and monolingual children based on age and nonverbal cognition, as well as language level is a complex and difficult one. On the one hand, one could match bilingual and monolingual children based on language level as follows: Bilingual children would be included in the study if they receive similar standard scores in the French and English tests, which might be taken as evidence that they have similar proficiency in both languages, but does not speak to how they compare with the monolingual children. Alternatively, as a group the bilingual children could be expected to receive similar standard scores on the CELF-P2 and PPVT-R as the monolingual English children as a group and similar standard scores on the N-EEL and the EVIP to the monolingual French children as a group. However, due to the distributed nature of the language knowledge of bilingual children, bilingual children would not necessarily be expected to score similarly to monolingual age mates in each individual language, as such an evaluation does not capture all their language knowledge (e.g. Elin Thordardottir, et al., 2006; Pearson et al., 1997; see however Elin Thordardottir (2008) who has shown that by the age of five, bilingual and monolingual children with a long term pattern of consistent equal exposure to two languages score similarly to monolingual children on a range of linguistic scores including vocabulary and grammar in comprehension and in production). Due to the complexity of matching bilinguals to monolinguals based on language level, the children in this study were matched on age and nonverbal IQ, while their verbal abilities were thoroughly evaluated allowing for later statistical comparisons to determine the effect, if any, of language skill differences. Furthermore, by striving to have as homogeneous a group of bilinguals as possible (simultaneous, equal exposure to each language), we minimized the risk that the bilinguals as a group would have different French and English abilities compared to each other.

Tasks and Procedures

All children were tested individually in a quiet room at the university, in their daycare, or in their home. Monolingual children were tested in a single 2 to 2 1/2 hour session by a native speaker of French or English. Bilingual children were tested in two separate 2 to 2 1/2 hour sessions, separated by at least 1 week, by a different native speaker of French or English (additional measures were administered which are not reported on here). The order of testing was counterbalanced across participants. Examiners included the first author for the English testing and a trained research assistant for the French testing.

Experimental Tasks

Verbal Memory Measures

These tasks were chosen to tap verbal and visual memory. The chosen tasks have been used extensively in the literature with children of all ages allowing for comparisons with findings from previous research.

Verbal Working Memory

The task used is a variant of the Daneman task and is a measure of verbal working memory which has been widely used with children. The French adaptation was developed by Elin Thordardottir (2006). Children listened to increasingly longer sets of sentences (sets of 2 to 6) and had to judge the truth value of each sentence; they were then asked to recall the final word of each sentence. The testing began with two trials consisting of 2 sentences in each set; the trials were repeated until the child understood the task. A total of 42 sentences were spoken by the examiner; the child answered yes or no to judge the veracity of the sentence after each sentence in the set was spoken then recalled the final word of each sentence once the examiner completed a set. In almost all cases, the children in this study were too young to understand that they only needed to repeat the final word and so tended to repeat the entire sentence; as long as the final word was mentioned, credit was given. Each child received two scores, one out of 42 for the truth judgement and the other also out of 42 for recalling the final word; both scores were converted to percentages. Bilingual children completed this task in English and in French in two separate sessions.

Verbal Short-term Memory

A test of nonword repetition and a test of digit span were administered to all children to assess verbal short term memory abilities in English and in French. The English nonword test was the Children's Test of Nonword Repetition (CNRep; adapted from Gathercole, Willis, Baddeley, and Emslie, 1994). The French nonwords were obtained from nonword lists developed by Courcy (2000). There are a total of 40 nonwords on both the English and French nonword repetition tests, ranging from 2 to 5 syllables in length and recorded by a native speaker of either French or English on an audio cassette. Children listened to each word and had to repeat the word exactly as they heard it. The final score was the total number of phonemes that the child repeated accurately converted to a percentage. The digit span measure was the Forward Digit Span subtest of the Clinical Evaluation of Language Fundamentals – Fourth Edition (CELF-4) (Semel, Wiig, & Secord, 2006) along with its French adaptation (Boulianne & Labelle, 2006).

Visual working memory

To assess the children's visual working memory capacities, a modified version of the pattern recall task devised by Jarrold, Baddeley, and Hewes (1999) was used, which involves the recall of positions of frogs on lily pads. In our computerized task, instead of frogs on lily pads, children were presented with Sponge Bob characters. Children were shown a matrix of cells (3 cm square) with Sponge Bobs appearing in half the cells; after a 2 second delay, the Sponge Bob characters disappeared and the child had to indicate by touching the location on the matrix, using a touch-screen, where the figures had been. Children were only allowed to make as many choices as there were Sponge Bobs. Recall was tested for 2, 3, 4, and 5 Sponge Bobs and with each increase in list size, the matrix increased by 2 cells; there were 5 trials at each list length leading to a total of 20 trials. Successful completion of four practice trials with a single Sponge Bob in a 2x2 matrix was required prior to administration of the experimental version. All children completed all 20 trials and received a score out of 20.

Controlled Attention in the visual domain

The task used has been utilized in previous research showing an advantage in controlled attention among bilingual children and adults. Using a response box attached to a laptop computer, participants were instructed to press a red button when a red square appeared on the computer screen, and to press a blue button when a blue square appeared. The red button was situated on the left and the blue on the right of the response box. The task started with 8 control trials where either a blue or red square randomly appeared in the *center* of the screen for 1500 ms after the presentation of a cue (800 ms) and a blank interval (750 ms). The purpose of the control trials was to familiarize the child with the task and to measure reaction time without the additional need to control attention in order to tease apart motor speed from controlled attention, if necessary. This was followed by 72 (36 congruent, 36 incongruent) test-trials presented randomly. Reaction time was measured starting at the onset of the stimulus and ending with the response. Each trial started with a cross in the center of the screen to get the child's attention; the cross remained on the screen for 800 ms, followed by a blank screen for 750 ms, and a red or blue square which remained on the screen for a maximum 1500 ms followed immediately by a square of the opposite colour for another 1500 ms. The next trial then began with another cross cue. Congruent and incongruent trials were presented in random order. A congruent trial consisted of a red or blue square appearing on the same side of the screen as its respective button. An incongruent trial consisted of a red or blue square appearing on the opposite side of its respective button.

Results

Background measures

Means and standard deviations on all background measures for all three groups are reported in Table 1. There were no significant differences between the three groups of children on any of these measures; therefore, the groups were matched on age, nonverbal IQ, SES (maternal education used as a proxy), receptive vocabulary, receptive morphosyntax, and verbal short-term memory (as measured by the digit span in each language). The CELF-P sentence structure subtest is a measure of receptive morphosyntax in English, while the NEEL 7 subtests are a measure of receptive morphosyntax in French.

Experimental measures

Means reported in percentages and standard deviations on the verbal short-term memory and verbal working memory scores are shown in Table 2. Analysis of variance was used to compare group means. There was no significant difference between groups on verbal working memory in either French (F (1, 28) = 0.869, p = 0.36) or English (F (1, 21) = 0.79, p = .38). There was no significant difference between the English monolingual and bilingual groups on verbal short term memory as measured by the test of nonword repetition (F (1, 26) = 1.11, p = 0.30). The bilingual group scored significantly better on the test of nonword repetition in French than the French monolingual group (F (1, 29) = 5.99, p < .05; partial eta squared = 0.17). Due to examiner error, one child in the bilingual group was not given the French versions of the verbal memory tasks, while two children in the bilingual group and five children in the English monolingual group were not given the verbal memory tasks.

The mean accuracy scores for the visual working memory task are presented in Figure 1; the total maximum score is 20. One child in the French monolingual group was not given the Pattern Recall task due to technical problems with the computer. There was no significant difference between groups on this measure (F (2,41) = 0.64, p = .0.53). Children's accuracy and reaction times (on correct trials only) on the Simon Task are reported in Figures 2 and 3. Reaction time measures reflect the average reaction time on all correct experimental trials. It should also be noted that, for the experimental trials, anticipatory responses, defined as those with a reaction time of 200 ms or less, were excluded from the total. There was no significant difference between groups on either speed (F (2,37) = 0.61, p = 0.55) or accuracy (F (2,37) = 0.00, p = 0.99) on the practice trials. There was also no significant difference between the groups on speed (F (2,42) = 0.55, p = 0.58) and accuracy (F(2,42) = 1.76, p = 0.18) on the experimental trials of the Simon Task. Because the bilingual children did not perform better than the monolinguals on either the Pattern Recall or the Simon tasks, and since they scored higher on the nonword repetition task, we did not consider further the potential role of French nonword repetition as a covariate, as had been planned.

To answer our second research question about the relationship between visuospatial working memory and performance on the Simon Task, a correlational analysis was conducted. Reaction times on the Simon Task correlated negatively with accuracy scores on the Pattern Recall Task, r = -0.44, p < .01 for congruent trials, and r = - 0.50, p < .01 for incongruent trials. Accuracy scores on the Simon Task correlated positively with accuracy scores on the Pattern Recall Task, r = 0.52, p< .01 for congruent trials, and r = 0.65, p < .01 for incongruent trials.

Given the significant correlation between performance on the Simon Task and accuracy on the Pattern Recall Task for all children as a group, we divided the children into groups in a different way to compare their performance on the Simon task. We performed a median split of the Pattern Recall scores resulting in two groups of children; those with high scores and a second group with low scores. There were six monolingual French-speaking children, 10 monolingual English children, and 7 bilingual children in the group ranking high on visuospatial working memory, meaning that the distribution of children in the high and low rank group on visuospatial WM was similar across language groups. The mean and accuracy scores on the Simon task according to rank on visuospatial working memory are reported in Figures 4 and 5. A repeated measures ANOVA with high and low Pattern recall scores as the between-subjects factor and congruent versus incongruent trials as the within-subject factor showed that the group who ranked high on visuospatial working memory also was faster on both types of trials of the Simon Task (F (1, 42) = 6.17, p < .02; partial eta squared = 0.13). A second repeated measures ANOVA on accuracy scores on the Simon Task showed the children who ranked high on visuospatial working memory were more accurate than those with low visuospatial working memory (F (1, 42) = 22.21, p < .001; partial eta squared = 0.35). We performed a similar analysis on the practice trials of the Simon Task; there was no difference on the practice trials of the Simon Task between children with high and low Pattern Recall scores.

Discussion

The main goal of the present study was to clarify the relationship between bilingualism and controlled attention by considering the contribution of verbal and visual working memory abilities. Two important conclusions can be drawn. First, bilingual and monolingual children showed similar performance on the Simon Task; a bilingual advantage was not observed. Early simultaneous bilingual children with approximately equal exposure to French and English from birth did not show an advantage in controlled attention, despite their fluent knowledge of the two languages. Secondly, a strong correlation was found between performance on a test of controlled attention and visual working memory such that children with better visual working memories performed significantly better on the Simon Task – they were faster and more accurate. Thus an advantage effect was indeed seen, only it related to working memory rather than bilingualism.

The finding that bilingual children show an advantage in controlled attention is not an uncontroversial one. Recently, Morton and Harper (2007) also found no advantage in controlled attention on the Simon Task in a group of French-English bilinguals who were matched on SES with their monolingual peers. One possible reason that our findings were at odds with some of the previous research on a bilingual advantage in controlled attention is that bilingual and monolingual children in the present study had comparable verbal and visual working memories, as well as language skills. Their French and English receptive vocabularies and grammar were equivalent to their monolingual peers in each language. We did not set out a priori to match the bilingual and monolingual participants on verbal and visual working memory. The bilingual children were recruited based on a strict amount of exposure to each language, as well as the age at which they began acquiring the two languages. We then ensured that, as a group, they were matched a priori with the monolingual children on age, maternal education, nonverbal cognition, and verbal short-term memory span. These selection and matching criteria interestingly resulted in a group of bilinguals who were also matched to their monolingual peers on verbal and visual working memory, as well as receptive vocabulary and grammar.

Furthermore, our bilingual participants formed a very homogeneous group as evidenced by age, length, and amount of exposure to each language. In previous research, many of the bilingual children were sequential bilinguals whose first language (L1) skills were not adequately measured; therefore it is possible that their L1 skills were highly under-estimated. The importance of simultaneous versus sequential bilingualism is acknowledged by Bialystok et al. (2005, p. 117): "… the subtle advantage in inhibitory control that comes from bilingualism is irrelevant for individuals who are already in control of efficient processing." It is reasonable to assume that a child who has been regularly and consistently exposed to two languages from birth switches between the two languages in a highly automatic way and no longer recruits controlled attention to do so when tested at the age of five. In contrast, a child who has been exposed to two languages since the age of three or four may still be switching between languages in a less automatic manner and using controlled attention to do so successfully.

In previous research, sequential bilingual children were tested at the ages of five and six years after only a couple of years of exposure to English, whereas their monolingual counterparts had been exposed to English since birth, giving them an edge of at least 2-3 years (Bialystok & Martin, 2004; Bialystok, 1999). For the sequential bilinguals in previous studies on the bilingual advantage, language processing in English and switching from the first language to the second is not as highly practiced as for the simultaneous bilinguals in our study – processing is more effortful and thus requires controlled attention. When they are then given a task that requires them to control their attention, they are more successful than the monolingual children who do not need to engage in this kind of effortful processing. Effortful processing does not appear to be a factor for our simultaneous bilingual children as they are efficiently processing both languages as well as the monolinguals, as evidenced by their equivalent verbal working memory and language abilities.

The differences in our results compared to previous studies could also be attributed partly to the nature of our testing sessions. We ensured that bilingual children were tested across two sessions (one in English and the other in French) separated by at least two weeks. We also ensured that the examiner was a different native speaker of each language and only spoke one language to the child at all times throughout the testing sessions. This is an important methodological difference due to the fact that bilinguals can function in a bilingual or a monolingual mode (Grosjean, 1998). In previous research on the bilingual advantage, the *same* bilingual examiner has run all tasks with the bilingual children and has spoken both languages to the child during that one session (e.g. Bialystok & Majumder, 1998). Therefore, the bilinguals were aware that the person testing them spoke both languages and very likely understood that they were being tested as bilinguals, a fact which may have affected how much or simply how they used one or another language; they were in a bilingual mode. In fact, Grosjean (1998) has suggested that the language mode variable might influence results obtained in bilingual studies. For example, during a bilingual session, bilingual children are switching from one language to the other and are actively practicing the control of their attention; then they are given a test of controlled attention. The monolingual children are not being tested under similar conditions.

A final reason for our failure to find a bilingual advantage in controlled attention is that the three groups of children were matched with respect to SES (maternal education). The relationship between SES variables and nonverbal development has been well documented (Rowe, Jacobson, & Van den Oord, 1999; Turkheimer, Haley, Waldron, D'Onofrio, & Gottesman, 2003; Epsy, Molfese, & DiLalla, 2001; Smith, Fagan, & Ulvund, 2002). Epsy et al. (2001) conducted a longitudinal study of children between the ages of three and six to determine the effects of SES on intelligence (as measured by the Stanford Binet). They found that the influence of SES differed for *verbal* and *nonverbal* abilities such that for the latter, initial SES influenced the amount of age-related change. Children from lower SES environments did not keep up with same age peers in nonverbal skill development, whereas small positive gains were observed in higher SES children. Mezzacappa (2004) has demonstrated that SES exerts a strong influence on the development of executive attention, a finding which is particularly relevant to the bilingual cognitive advantage literature. This brief discussion of studies about SES is not done to conclude that this variable on its own *causes* children to become 'smarter' or bilingual; such a conclusion cannot be drawn from the research. However, it is highly plausible that children who grow up with parents who are more educated create greater opportunities which enhance their verbal as well as nonverbal abilities.

Our second finding was that visual working memory is highly correlated with controlled attention and that children with better visual working memories are faster and more accurate on the experimental (and not practice trials) of the Simon Task. Some direct support for our finding comes from a recent study on the bilingual advantage in controlled attention with adults (Bialystok, Craik, Luk 2008). One of the background measures in this study was the backward Corsi span task, used as a measure of visual working memory. The bilinguals recruited for this study had better visual working memories than the monolinguals and, not surprisingly, they also did better on the Simon Task. A correlational analysis between visual working memory and the Simon Task was not done in the Bialystok et al. (2008) study, nor was visual working memory treated as a covariate when the bilingual and monolingual groups were compared; the conclusion was that bilingualism leads to an advantage in controlled attention. However, given the strong correlation we found between visual working memory and controlled attention, it is reasonable to infer that the advantage in controlled attention can, at least, be partially attributed to better visual working memory capacities in the bilingual adults.

It must be noted at the outset that finding an association between visual working memory and controlled attention does not necessarily imply a causal relationship – but it does suggest that the association is a reliable one given the fact that a useful function of correlational analysis is theory verification and our findings support the theory put forward by Engle et al. (1999). Recall that the Engle et al. (1999) model and the research supporting it show that individual differences in WM capacity may actually determine the ability to control attention. The explanation given for this has been that greater WM capacity may mean greater ability to use attention to avoid distraction and that dealing with the effects of interference (that is, controlled attention) is one of the primary functions of working memory. However, the finding that visual and not verbal working memory was associated with performance on the Simon Task is inconsistent with the notion that working memory capacity is driven by a domain-general mechanism (Baddeley, 1999; Engle et al., 1999). Instead it is more consistent with the view of domain-specific constructs for verbal and visuospatial memory measures (Alloway, Gathercole, & Pickering, 2006; Miyake et al., 2001; Shah & Miyake, 1996). One reason for this could be that our population formed a very homogeneous one, so that the range of cognitive abilities was restricted – this point has also been made by others (Shah and Miyake, 1996).

The present results suggest that simultaneous bilingual and monolingual children who are matched on multiple variables, including working memory and language are similar in their abilities to control attention. Our findings also show that children who have better visual working memory capacities perform better on the Simon Task. A strength of this study is that the bilingual children formed a highly homogeneous group and were matched to monolingual children on a number of variables. Furthermore, bilingualism was strictly operationalized;

however, the results remain only suggestive at this stage given that a number of studies have found an advantage in controlled attention for bilinguals. The bilingual advantage has been attributed to the belief that both languages are active at all times and that speaking one fluently requires the inhibition of the other (Green, 1998); this continued practice with controlling attention spills over into nonverbal tasks. The results of the present study showed that, in the case of balanced, highly proficient, simultaneous bilingual children, this does not seem to be the case. It remains to be seen whether in a group of sequential bilingual children who are matched along the same variables as in this study with their monolingual peers, an advantage in controlled attention will be observed.

Tables and Figures

Table 1.
Participant characteristics, background and language measures, means and (SDs) for monolingual English-speaking children (EML), bilingual children (BL) and monolingual French-speaking children (FML)

	EML	**BL**	**FML**
Age in months	59.5 (4.4)	58.7 (4.2)	59.4 (4.9)
Gender	6 M, 9 F	6 M, 9 F	5 M, 10 F
Maternal ed.	16.8 (2.7)	17.9 (2.7)	15.9 (2.2)
Leiter-R	105.5 (11.6)	107.6 (13.4)	105.4 (13.2)
PPVT	111.3 (13.1)	100.1 (17.97)	---
EVIP	---	106.3 (14.1)	109.5 (16.7)
English digit span	5.9 (1.7)	6.1 (1.2)	---
French digit span	---	6.3 (2.1)	5.9 (2.6)
CELF-P	10.2 (2.2) (N=12)	9.6 (3.4) (N=13)	---
NEEL 7		3.8(1.6)(N=9)	4.4(1.0(N=9)

Note:
EVIP, CELF-P scores are standard scores
NEEL 7 is a raw score out of 6
Leiter-R scores are standard scores for Brief IQ
Maternal education is reported in years of school completed including elementary school and all subsequent levels.

Table 2.
Verbal memory measures, means and (SDs) reported as proportions for monolingual English-speaking children (EML), bilingual children (BL) and monolingual French-speaking children (FML)

	EML	**BL**	**FML**
CLPT – French	---	0.38 (0.10)	0.34 (0.14)
CLPT – English	0.36 (.09)	0.29 (0.17)	---
Fr Nonword repetition	---	0.91 (0.04)	0.87 (0.05)
Eng Nonword repetition	0.91 (0.07)	0.86 (0.18)	---

Figure 1.
Raw accuracy scores out of a possible maximum of 20 on the Pattern Recall Task – a measure of visuosptial working memory

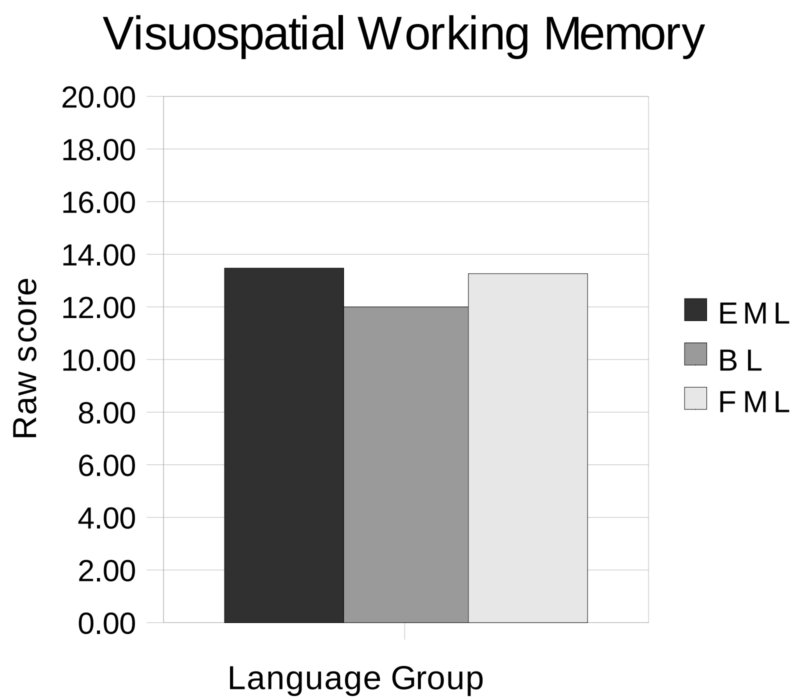


Figure 2.
Mean Reaction times in milliseconds as a function of language group on the Simon Task

Figure 3.
Mean accuracy in percentages as a function of language group on the Simon Task

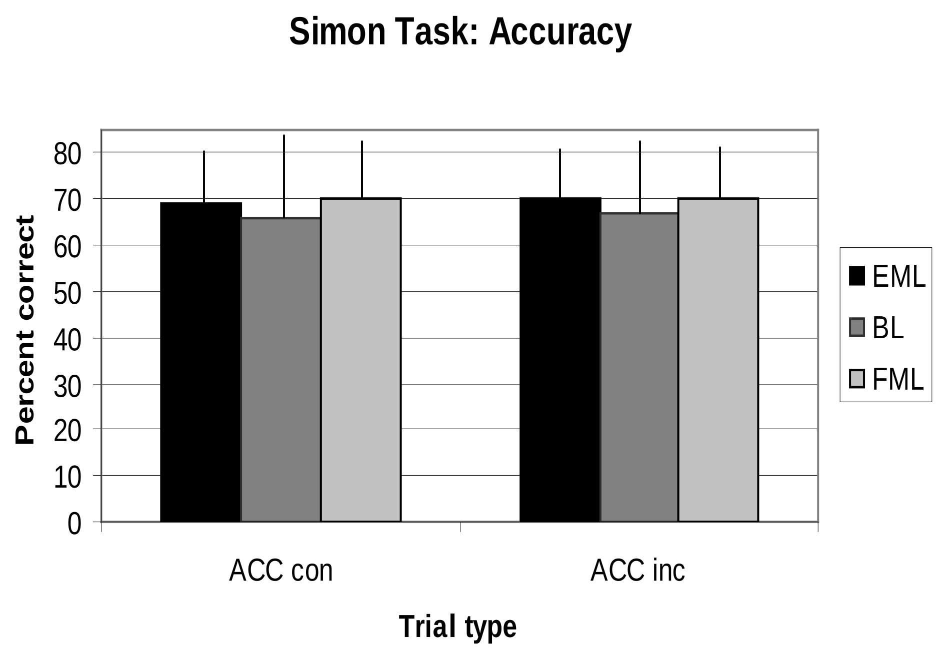


Figure 4.
Mean Reaction times in milliseconds as a function of visuosptial working memory on the Simon Task

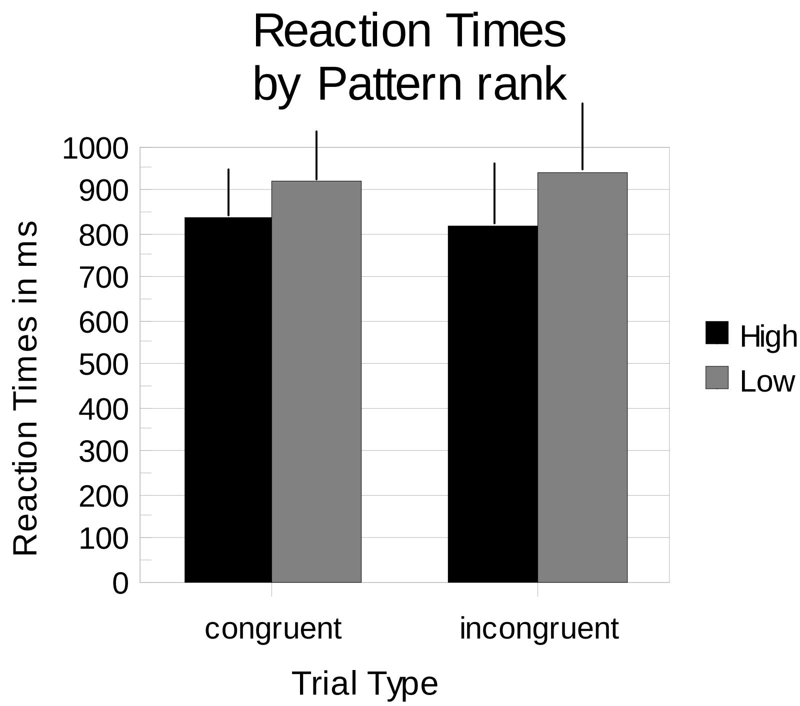
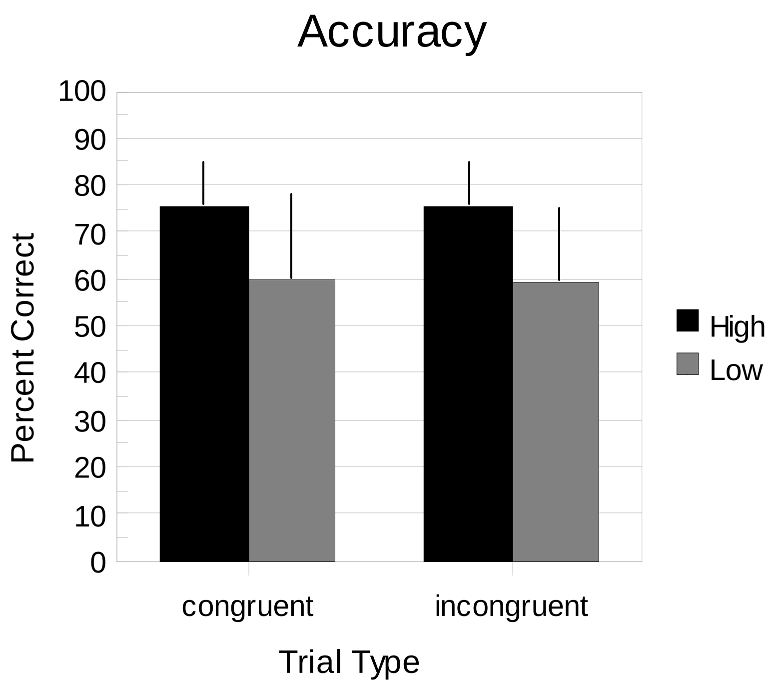


Figure 5.
Mean accuracy in percentages as a function of visuospatial working memory on the Simon Task



Preface to the Second Manuscript

The first manuscript attempted a replication of the controlled attention advantage reported in balanced bilingual preschool-age children on the Simon task. It was found that when children were equated on visual and verbal measures of working memory, they performed equivalently on the Simon task, a visual measure of controlled attention. In the second study, on which we report in the next manuscript, we were interested in comparing these same three groups of children on an auditory measure of controlled attention. We simulated one of the real-world experiences of a bilingual individual who is listening to conversation in one language and hears speech in the other language but needs to ignore it in order to successfully understand the relevant conversation. This ability has been reported as the basis for the bilingual individual`s domain-general enhancement in controlled attention.

Distraction by meaningful competing speech: A bilingual or working memory advantage

Mahchid Namazi and Elin Thordardottir

Abstract

Previous research on the superior controlled attention abilities of bilingual children has posited that this skill arises from the child's continued practice with ignoring the irrelevant language and attending to the relevant one (Bialystok, 1999). However, it is unclear how bilingual children perform relative to monolingual ones on the very kind of task which reportedly leads to the observed advantage in visual controlled attention. We examined whether bilingual and monolingual children differ on a verbal measure of auditory controlled attention simulating the bilingual experience. A second aim was to look at the relationship between auditory controlled attention and verbal memory. The same 15 French monolingual children, 15 English monolingual children, and 15 early simultaneous French-English bilingual children as in study one completed verbal memory and controlled attention tasks. A bilingual advantage in auditory controlled attention was not found; monolingual and bilingual children were equally successful in ignoring the competing story and attending to the target sentence comprehension task. Furthermore, verbal working memory correlated significantly with auditory controlled attention, in French. We discuss results in relation to differential effects for English and French, as well as for the bilingual and monolingual children.

Introduction

The effects of early experience on cognitive functions have been studied by various researchers in the last decade (e.g. Dawson, Ashman, & Carver, 2000). For example, Ho, Cheung and Chan (2003) found that children with music training had better verbal memory than those without such training. In recent years, research has indicated that fluently bilingual children excel at nonverbal tasks requiring controlled attention when compared to their monolingual peers (e.g. Bialystok, 1999; Bialystok & Martin, 2004; Bialystok, Martin, Viswanathan, 2005; Bialystok & Senman, 2004; Bialystok & Shapero, 2005). Controlled Attention (CA) has been broadly defined as the ability to direct attention to specific aspects of a stimulus field or mental representation during *real-time* problem solving and becomes particularly important when there is conflict in the form of irrelevant information. A bilingual advantage in CA has been observed across the lifespan on a variety of different nonverbal tasks (Bialystok, 1999; Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok & Martin, 2004; Bialystok & Senman, 2004; Bialystok & Shapero, 2005).

The advantage in controlled attention on nonverbal visual tasks has been said to arise from the bilingual's continual practice with ignoring the non-relevant, other language in order to communicate effectively in the relevant one. Over time, this continual practice in the verbal domain through the auditory modality is thought to generalize to cognitive processes that are general and non-linguistic in nature and presented in the visual modality (Bialystok, 1999). However, the finding that bilingual children outperform monolinguals on nonverbal conflict tasks in the visual modality is a curious one, particularly since the research on the consequences of different life experiences on cognition overwhelmingly supports the conclusion that cognitive changes are related to the specific areas being practiced (e.g. Green & Bavelier, 2003; Feng, Spence & Pratt, 2007; Salthouse & Mitchell, 1990). For example, video game players enjoy enhanced abilities in *visual* selective attention (Green & Bavelier, 2003) and London taxi drivers have enlarged regions of the hippocampus in charge of *spatial* navigation (Maguire et al., 2000). So why is it that, in the case of the recent literature on bilingualism, an advantage on conflict tasks is reported primarily in the visual modality? Although, as will be reviewed below, advantages have been reported in the auditory-verbal modality as well, what remains to be clarified is how bilingual children perform in relation to their monolingual peers on an auditory verbal task where they need to ignore one language while attending to the other. That is, how do they perform on the very kind of task which is reported to lead to the observed advantage in controlled attention in the visual modality?

The advantages of bilingualism on verbal conflict tasks that have been reported are in the metalinguistic domain. For example, bilingual children have been shown to outperform monolinguals on verbal tasks of metalinguistic awareness at the word and sentence level. Ianco-Worrall (1972) was one of the first to show that bilingual children do better than monolingual ones on a metalinguistic task of separating sound from word meaning and in perceiving the relationship between words in terms of their symbolic rather than their acoustic properties. The finding that bilingual children showed superior performance on such symbol substitution tasks was replicated by others (Ben-Zeev, 1977; Cummins & Mulcahy, 1978). Bialystok (1986) was the first to interpret such findings as bilingual children being better able to suppress the irrelevant information and attend to relevant cues, following her finding that young bilingual children were better in a word size judgment task. Specifically, on words where there was a mismatch between the size of the word and its referent (e.g. train/caterpillar), bilingual children did not seem to be distracted by the length of the word. Bialystok (1998) went on to further examine the metalinguistic skills of two groups of grade one bilingual children with differing levels of language proficiency. All the bilingual children outperformed the English monolingual children on the task addressing the arbitrariness of word length. Bialystok's re-interpretation of the findings from a large body of metalinguistic studies concluding that bilingual children possess an advantage in controlled attention was pivotal in inspiring research over the last decade trying to uncover and more specifically define the bilingual advantage. A recent example with the adult population is that of Ransdell, Barbier, and Niit (2006) who showed that bilingual and multilingual university students have better metalinguistic awareness of their language skills in reading and in working memory than do monolingual students with comparable native language skills. Their interpretation for this advantage is the "lifetime of experiences bilinguals have in activating and inhibiting language codes" (Ransdell et al., 2006, p. 738).

However, superior performance on such verbal conflict tasks does not require actively suppressing meaningful and competing verbal information in the other language presented in the auditory modality, which is what bilingual individuals must do at all time. For example, a classic task is the semantic anomaly task (e.g., Bialystok 1986). In this task, children are presented with sentences and asked to judge whether or not they are grammatical. Some sentences are actually ungrammatical while others do not make sense semantically (e.g., cats bark). Bilingual children outperform monolingual same age peers on the judgment of semantically anomalous sentences; that is, they still judge those as grammatical and are not distracted by the irrelevant semantic anomalies. This kind of task is not directly comparable to that of ignoring one language while attending to the other; it is not clear how the two are related or whether they should lead to a general advantage in controlled attention.

Processing speech in quiet and in the presence of noise

Speech perception studies in bilingual infants are abundant but the focus has been on the discrimination of phonetic level contrasts (Sundara & Polka, 2008; Burns, Yoshida, Hill, &Werker, 2007; Werker et al., 2007) and not the processing of meaningful sentence level language in context. These studies have shown that bilingual infants and toddlers are on par with their monolingual peers in processing the phonetic details required for the acquisition of their languages. The effect of background noise on speech perception in children has also been investigated (e.g., Elliot et al., 1979; Fallon, Trehub, & Schneider, 2000). Monolingual children's perception of speech in multitalker babble relative to that of adults has been investigated showing that children required more favorable signal to noise ratios to achieve comparable performance in low noise (Fallon, Trehub, & Schneider, 2000). In this latter study, five-year old children were asked to touch the correct picture on a computer screen to demonstrate understanding of 40 monosyllabic nouns in the presence of background noise in the form of multitalker babble.

Research with adult monolinguals investigating the cocktail party phenomenon has shown that individuals with low working memory spans recall their own name in an unattended message, while those with high working memory capacities were more successful in ignoring their name in the irrelevant message (Conway, Cowan, & Bunting, 2001). Other research has shown that older adults' reduced efficiency in controlled attention is a crucial factor in their difficulty in recalling target speech in the presence of a background of competing speech (Tun, O'Kane, & Wingfield, 2002). The research done with monolingual individuals looking at the effects of background noise on speech processing is related to the ability to control attention.

Much less research is available on speech perception in noise with bilingual children. Nelson, Kohnert, Sabur, and Shaw (2005) looked at the effect of classroom noise on attention and speech perception in children learning English as a second language (L2). They found that word recognition performance was reduced significantly for L2 children relative to their monolingual English counterparts. Much more research has been done with adult bilinguals investigating the processing of speech in noise (e.g. Bahrick, Hall, Goggin, Bahrick, & Berger, 1994; Mayo, Florentin, & Buus, 1997; Von Hapsburg, Champlin, & Shetty, 2004; Rogers, Lister, Febo, Besing, & Abrams, 2006).

However, what is common to such studies is the use of white or babble noise and nonmeaningful speech. Furthermore, the focus has been on exploring issues such as language dominance with little attention being paid to equating bilinguals and monolinguals on measures of nonverbal cognition, working memory, and language abilities. Because the focus has been on dominance, participants are learners of English as a second language and thus have acquired English after early childhood. Finally, all tasks have been given in English without comparison to the other language. The research cited above with adult bilinguals has shown that the ability to ignore one language while performing in another is somewhat dependent on level of language proficiency, age, and amount of exposure to the language. Adults who have acquired the second language at a later age, have not been exposed to that language as long as the monolingual comparison groups, and who are not as proficient, perform less well (than adult monolinguals) when listening to the second language in the context of background noise.

Controlled Attention, Working Memory and Language Comprehension

The role of controlled attention in language comprehension is highlighted by Nation, Marshall, and Altmann (2003), who found a positive relationship between the ability to suppress irrelevant information and real-time sentence comprehension in children. Children assessed as good language comprehenders were more successful on a test of controlled attention relative to poor comprehenders of the same age. In typically developing children, controlled attention has been correlated with language ability in monolinguals at varying linguistic levels (Wolfe & Bell 2004), with Theory of Mind abilities (Hughes

1998), and with mathematical abilities (Epsy et al., 2004). Therefore, controlled attention is a cognitive construct that seems to be central to achieving success on a variety of different cognitive tasks, including language.

Engle, Kane, and Tuholski (1999) proposed a model of working memory (WM) that clearly specifies the role of controlled attention, which is the cognitive construct currently at the centre of the bilingual advantage literature. This model details a more continuous relationship between WM, short-term memory (STM) and controlled attention. In this model, the underlying WM construct is viewed as continuous, ranging from individuals who have *more* attentional resources (or can regulate resources more effectively) to those who have *fewer* resources (or who regulate less well) (Barrett, Tugade, & Engle, 2004). Engle and colleagues have shown that individual differences in WM capacity may actually determine the ability to control attention. For example, Rosen and Engle (1998) demonstrated that the ability to suppress intrusive thoughts and behaviours, a skill requiring controlled attention, is highly dependent on an individual's WM capacity. Engle (2002) also showed that controlled attention varied as a function of WM capacity; that is, greater WM capacity may mean greater ability to use attention to avoid distraction and that dealing with the effects of interference (that is, controlled attention) is one of the primary functions of working memory.

Sentence comprehension has also been linked to working memory abilities as well as the ability to suppress irrelevant information (controlled attention) in both typical children and children with language disorders (e.g. Nation et al, 2003; Montgomery, 2000a, 2002, 2003). Engle et al. (1999) also highlighted the important relationship between WM capacity and language abilities. For example, in two longitudinal studies with children, WM and listening comprehension tasks were given to 3.5, 4.5, and 5.5-year-old children. WM measures for each year predicted the subsequent year's comprehension scores, whereas WM could not be predicted by comprehension scores. Adams, Bourke, and Willis (1999) found that spoken language comprehension was associated with both listening span and phonological memory and not visuospatial memory, in a group of 5-year old children.

The current study

In this study, we were interested in whether bilingual and monolingual children differed on a verbal measure of auditory controlled attention that simulated the bilingual experience of attending to one language while ignoring the other. Given the evidence showing links between sentence comprehension and working memory as well as controlled attention, a second aim was to look at the relationship between auditory controlled attention and verbal working memory. In this study, auditory controlled attention refers specifically to attending to a speaker in one language while ignoring irrelevant, but meaningful, discourse taking place concurrently in the other language in the background, at a reduced volume. Such an auditory task mimics the task bilingual children face daily and which has been suggested to give rise over time to a domain-general advantage in controlled attention.

At issue is whether bilingual children are able to direct their attention to one language only when meaningful information is being presented in both languages. If, during such a task, bilingual children activate both languages in parallel during comprehension, they will face higher processing demands and thus should make more errors than monolingual children when presented with the target task in one language and asked to ignore meaningful competing discourse in the other language. That is, for the monolingual children, the other language is not meaningful, thus in theory, their attention should not be drawn to it. If, on the other hand, as Green's model (1998) would predict, bilinguals successfully inhibit meaningful competing discourse in one language while attending to a target task in the other language, there should be no performance differences between groups of monolingual and bilingual children. Therefore, as is predicted in the bilingual advantage literature, the bilingual children might demonstrate an advantage gained through continual practice. If, however, the bilingual children exhibit significantly lower performance on the target task in this interlingual condition, this would be taken as evidence that they are not fully capable of inhibiting their other language. In a second condition, the target and distractor are presented in the same language (intralingual condition). In theory, bilingual children have developed an enhanced ability to ignore distracting information through continual practice dealing with two *different* languages; however, they presumably spend some of their time ignoring distracting information in the same language. Therefore, bilingual children would be predicted to perform as well as the monolingual children on such a task, as the distractor is now equally meaningful to both groups. We chose to use meaningful discourse in the form of a narrative as opposed to 'cocktail party conversational noise' in order to simulate the real-world situation where a bilingual person is having a conversation in one language while attempting to ignore a nearby conversation in the other language. In summary, we wanted to test bilingual children on the very skill that has been given as the foundation for the development of an advantage in controlled attention.

Methods

Participants

We included 45 children divided into three groups of 15 French monolinguals (mean age of 59.4 months), 15 English monolinguals (mean age 59.5 months), and 15 French-English simultaneous bilinguals (mean age 58.7 months). All children passed a hearing screening at 10 dB HL under earphones at octave frequencies from 500 to 4000 Hz. Reliable results could not be obtained at 500 Hz for some children because testing was not completed in a soundproof booth. Children were matched groupwise on age (p = .84), nonverbal IQ (p = .87) using the Leiter International Peformance Scale-Revised (Roid & Miller, 1997), and maternal education (a proxy for socio-economic status (SES)) (p = 0.08). Children were recruited from local preschools and daycares in the greater Montreal area and in Vancouver for six of the monolingual English speakers. Patterns of amount, length, and age of exposure to each language, relative proficiency in French and English, medical history, developmental history, and family structure were verified by completion of a detailed parent questionnaire (Elin Thordardottir, Rothenberg, Rivard & Naves, 2006). Language proficiency was further verified by language testing. Only children who had been exposed to

English and French equally, on a regular basis from before the age of 3 years and with no significant exposure to any other language were included in the bilingual group. For the monolingual group, children were required to have been exposed to French or English consistently from birth with no significant exposure to any other language.

Children who met the criteria outlined above for inclusion in the bilingual or monolingual groups were seen for further testing. Children were given a test of forward digit span in English, French, or both (if bilingual), as well as a pattern recall test assessing visuospatial memory. Children's verbal abilities were tested in the appropriate language/s. In French, subtests of the Nouvelles épreuves pour l'examen du langage (NEEL) (Chevrie-Muller & Plaza, 2001) and the Échelle de vocabulaire en images Peabody (EVIP) (Dunn, Thériault-Whalen & Dunn, 1993) were used, while in English, the Clinical Evaluation of Language Fundamentals-Preschool Second Edition (CELF-P2) (Semel, Wiig, & Secord, 2003) and the Peabody Picture Vocabulary Test- Revised (PPVT-III) (Dunn & Dunn, 1997) were used. The EVIP and PPVT-III are standardized tests of receptive vocabulary in French and English, respectively. The NEEL subtests assess receptive and expressive vocabulary, grammar, and morphosyntax in French, while the CELF-P2 evaluates these parameters in English. Participant characteristics are summarized in Table 1. The participants were part of a larger study on language and cognitive development in bilingual children (Elin Thordardottir, 2008a; Namazi & Elin Thordardottir, submitted). The sample reported on here is the same as that in Namazi & Elin Thordardottir, which examines the children's performance on controlled attention in the visual domain.

Due to the distributed nature of language knowledge in bilingual children and the complexity of matching them to monolingual children based on language abilities (see Elin Thordardottir et al., 2006; Namazi & Thordardottir, submitted; Pearson, Fernandez, & Oller, 1997), matching was done on the basis of age, nonverbal IQ, and SES. We did not attempt to match the bilingual children to monolingual children in each language; instead language abilities were thoroughly evaluated so that potential differences could be accounted for. Elin Thordardottir (2008a) has shown that by age 5, French/English bilingual children in Montreal who have been exposed regularly to each language over much of their lives score comparably to monolingual children on various tests of language comprehension and production in each of their languages.

Procedures

All the children were tested by a native speaker of either English or French, individually in a quiet room at the university, in their daycare, or in their home. Testing for the monolingual children was a single 2 to 2 1/2 hour session, while the bilingual children were seen in two separate 2 to 2 1/2 hour sessions, separated by at least 1 week. The order of testing was counterbalanced across participants. Examiners included the first author for the English testing and a trained research assistant for the French testing.

Experimental Tasks

Verbal Memory Measures

The children's verbal working memory was assessed as part of the larger study in which they participated with the Competing Language Processing Task (CLPT) (Gaulin & Campbell, 1994), which has been reported on in detail in Namazi and Elin Thordardottir (submitted). The French adaptation used was developed by Elin Thordardottir (2006). The task involves judging the veracity of sets of sentences while memorizing the final word of each sentence. A test of nonword repetition and a test of digit span were administered to all children to assess verbal short term memory abilities in English and in French. The English nonword test was the Children's Test of Nonword Repetition (CNRep, Gathercole, Willis, Baddeley, & Emslie,1994). The French nonwords were obtained from nonword lists developed by Courcy (2000).

Auditory Controlled Attention

The main focus of this study is on auditory comprehension of sentences in the presence of meaningful linguistic material presented in the same language or other language of the bilingual children. This task was developed expressly for this study. The comprehension stimuli included computerized versions of the Test for Auditory Comprehension of Language-Revised (TACL-R) (Carrow-Woolfolk, 1999) in English and a Quebec French adaptation commonly referred to as "Le Carrow", which involved standardization for young school-aged children and has been in substantial clinical use (Groupe coopératif en orthophonie - Région Laval, Laurentides, Lanaudière, 1995). The TACL-R is composed of three subtests and includes stimuli of varying length and complexity that test 3 to 9-year old children's ability to understand different grammatical constructions. The first subtest evaluates word-level semantic comprehension of a variety of linguistic concepts. The second subtest tests the comprehension of grammatical morphology at the sentence level. The final subtest evaluates the comprehension of sentences with increasing syntactic complexity and length. Stimuli are ordered and administered according to increasing level of difficulty. In the French adaptation (Groupe coopératif en orthophonie - Région Laval, Laurentides, Lanaudière, 1995), items were reordered to match the order of grammatical development in that language based on testing. The sentences from subtests II and III (morphosyntax and complex sentences) of the TACL-R (French and English) were divided into two lists, in each language, equated for level of difficulty; the odd numbered sentences made up one list and the even numbered sentences made up the other list. This procedure resulted in four lists of 18 sentences, two in English and two in French. Each of the lists in either language was then paired with a background story in either French or English, resulting in two general conditions: (1) target and competition in the same language ("intralingual" condition: EE: target and competition in English; FF: target and competition in French) and (2) target and competition in different languages ("interlingual" condition: EF: target in English, competition in French; FE: target in French, competition in English).

The meaningful auditory distraction (competition), presented simultaneously with the comprehension stimuli, was a story familiar to young children recorded by two different female native speakers of English and French. The English story was “Franklin in the Dark” and the French story was “Le doudou de Benjamin”. Franklin, in English, and Benjamin, in French, is a turtle that figures in a series of children’s books written by Paulette Bourgeois and Brenda Clark. The stories were of similar length and theme. The stories were chosen such that they took as much time to listen to as it did to complete the sentence comprehension task. The sentences (target) were on average 10dBA louder than the background story (competition); a +10dB SNR was chosen based on previous research with young bilingual children looking at the effects of typical classroom noise on speech perception (Nelson et al., 2005).

Sentences were digitized and stored as waveform files; the resulting waveform files were then made available to software for running the experiment (Superlab for Windows 2.0). For each of the sentences, a 640 X 480 pixel visual scene consisting of three rectangles was shown on a computer with a touchscreen. These pictures were scanned into the computer from the TACL-R/CARROW picture manual. Children were seated in front of a 14-inch laptop with a touchscreen attached. The children were given the following instructions: “You will see three pictures at a time on the screen while you listen to sentences. You need to touch the picture on the screen that goes with the sentence you hear. Wait until the sentence is finished before you touch the picture. Someone else will be talking while you are listening to the sentences; don’t listen to that person; only listen to the one who’s telling you about the pictures.” Once the child had responded, the next sentence was made available. All children completed a practice trial of 8 sentences in quiet in order to ensure that they understood the task. At the completion of the experimental task, the child was asked two questions about who and what the story was about; this was done in order to verify story recall despite being told to ignore it.

All children completed the sentence comprehension task (target) while simultaneously listening to each story in each language; this was done in order to determine whether there was a differential effect on comprehension and controlled attention based on the language of the background story. The monolingual children completed one intralingual and one interlingual condition where the target sentences were always in the language they spoke. The bilingual children completed two intralingual and two interlingual conditions where the target sentences were in either English or French, across the two different language sessions. The order of list presentation was counterbalanced such that half the children did the English lists first and the other half did the French lists first.

Results

Measures of Language and Memory Abilities

Measures of language proficiency and memory were administered to document the children's performance in these areas, although they were not part of the matching procedure. Group comparison on these measures revealed that there were no significant differences among the three groups of children on receptive vocabulary, receptive morphosyntax, digit span, verbal working memory (CLPT), or verbal short term memory (CNRep). Means and standard deviations for these tasks are reported in Namazi & Elin Thordardottir (submitted). Table 1 shows participant characteristics.

Auditory Controlled Attention

Group means and standard deviations of accuracy scores on the auditory test of controlled attention are reported in Table 2. Due to examiner error, one child in the bilingual group did not complete this task. The maximum raw accuracy score possible on each list was 18. Results will be discussed in terms of interlingual and intralingual conditions where the target is the sentence comprehension task and the competitor is the background story. The language in which the targets were presented will always be listed first followed by the language of the competitor. For example, FE is the French *inter*lingual condition because the targets were presented in French and the competitor was presented in English, whereas FF is the French *intra*lingual condition (targets and competitor are in the same language).

Before turning to the accuracy scores, we will report on an informal assessment that was conducted to check the children's recall of the content in the competitor story by asking them the two following questions: "do you know who the story was about?" and "do you know what the story was about?" Only four children could tell us who or what the story was about. Three of these children were in the bilingual group and one was in the English monolingual group. The three bilingual children accurately recalled who as well as what the background story was about in all four conditions; that is, they were able to give details as to the content of the competitor story. The English monolingual child only recalled who the story was about and only in the English intralingual condition. Recalling significant details from the competitor story did not impair the performance of the bilingual children on the target task, as they were actually among the highest scoring individuals on the test of auditory controlled attention.

To compare bilingual and monolingual children's accuracy on auditory controlled attention, two repeated measures ANOVAs were conducted, with one comparing the bilingual and French-speaking monolingual children on accuracy of French targets, and the other comparing the bilingual group and the English-speaking monolingual group on accuracy of English targets. In each ANOVA, therefore, group (monolingual vs. bilingual) was the between subjects factor and accuracy on the auditory controlled attention task was the dependent variable with language of the competitor (interlingual vs. intralingual condition) treated as repeated measures. Because we had two monolingual groups who completed the task in two different languages, two separate ANOVAs had to be completed in order to compare each monolingual group to the bilingual group in each language. No significant group differences were found in either ANOVA. Thus, the performance of the bilingual children was equivalent to that of the monolingual children whether they completed the task in French (p = 0.58) or in English (p = 0.12). In the ANOVA testing accuracy with targets in French, there was a within-subjects effect of the competitor language, such that mean accuracy was lower in the French intralingual condition (FF) as compared to the French interlingual condition (FE) ($F(1, 27) = 5.73$, $p = .02$; partial eta squared = 0.18). There was no significant interaction effect between group and language of the competitor, meaning that this pattern was true for both the monolingual and bilingual groups of children who completed the task in French. No effect was statistically significant for children tested in English.

The bilingual children completed the task in two different languages unlike the monolingual children. The previous ANOVA included a within-subject comparison of FF vs. FE as well as EE vs. EF. However, the ANOVA could not include a comparison of all the conditions administered to the bilingual children because each ANOVA only considered those conditions in which the target language was shared by the bilingual and monolingual groups. The remaining conditions, yielding the following four planned comparisons using paired t-tests, were: 1) FE vs. EE 2) FE vs. EF 3) FF vs. EE 4) FF vs. EF. In order to guard against the probability of Type I error resulting from these multiple comparisons, a Bonferroni correction was used, such that the critical alpha level for the comparisons in the bilingual group was p =.01 (.05 /4). We obtained significant results for FE (mean 12.0) vs. EF (mean 8.5) (t = 5.62, p = 0.00 with a mean paired difference of 3.54), as well as FE (mean 12.0) vs. EE (mean 9.1) (t = 7.30, p = 0.00 with a mean paired difference of 3.23). The other two pairs did not yield a significant difference (FF (mean 9.7) vs. EE (mean 9.1), p = 0.16; FF (mean 9.7) vs. EF (mean 8.5), p = 0.12). The bilingual children clearly performed best when the targets were in French and the competitor was in English, that is, in the French interlingual condition.

An individual level analysis was also done in order to further clarify the effects of the different conditions. This analysis showed that eight of the bilingual and eight of the French monolingual children received their highest score of the four conditions, on the French interlingual condition. Although the French interlingual condition was easiest for most of the children, it was not the case for *all* children who completed the task in French. Four bilingual children and five French monolingual children received their highest score on the French intralingual condition. Two French monolingual children received equivalent, but low scores (relative to other children), on the French interlingual and intralingual conditions. One bilingual child got the highest score on the English interlingual condition. The remaining bilingual child received equivalent scores on the French and English interlingual conditions, which were also higher than both intralingual conditions. Therefore, a little more than half of the children (16/29) who completed the task in French did best in the French interlingual condition, while only nine of 29 did best on the French intralingual condition.

The results of the repeated measures ANOVAs above clearly show that the performance of the French monolingual children as well as the bilingual children in French was lower in the FF as opposed to the FE condition. This latter finding suggests that the French stimuli used in these two conditions might not have been equivalent in level of difficulty (recall that no significant difference was found for either group for the EE and EF conditions – therefore, this difference between the intra and inter-language conditions appeared only in French). Different lists were used for the FF and FE conditions throughout, without counterbalancing of targets across the two competing story conditions (the same was true for the English stimuli). Consequently, an additional analysis was undertaken to evaluate the equivalence of the two lists of French target sentences. We compared the performance of the French monolingual and bilingual groups on the French auditory controlled attention task to that of a third group of twenty French monolingual children of the same age (mean = 58.4; $p = 0.81$) who had completed the sentence comprehension task in quiet as part of a different study (Elin Thordardottir et al., 2007). This group of children was randomly selected for this comparison from a larger dataset of monolingual French-speaking children from Montreal, evidencing normal language development, based on age. From these children's forms, scores were computed for the lists as used in the FE and FF tasks in the present study. Group accuracy means for this group were 14.75 (SD = 2.1) for the FE list and 14.35 (SD = 2.0) for the FF list. A paired samples t-test comparing these children's performance on these two lists of French stimuli showed no difference between performance in quiet on the two lists for this group, ($p = 0.41$), signifying that the two lists of French stimuli were, in fact, equivalent in difficulty. This suggests, in turn, that observed differences in the FE versus the FF conditions are not related to the lack of equivalency in difficulty between the two lists, but rather to the combination of language of the target and language of the competitor.

Given the fact that the bilingual group seemed to do better when the targets were in French, a second possibility that needs to be considered is that the English and French targets may have differed in level of difficulty. This is an unlikely possibility for several reasons. First, the French version of the sentence comprehension task was adapted from the English and re-normed to corroborate with the development of morphosyntax in French. Second, the bilingual children did not always score higher when the targets were in French as compared to when the targets were in English. The planned comparisons above clearly show that the bilingual children did not score any better in the French intralingual condition when it was compared to the English intralingual condition (EE) or the English interlingual condition. Furthermore, there was no group effect as reported in the repeated measures ANOVA; that is, the task was equally difficult for all children, whether it was completed in French or in English.

Given the availability of a group to whom the stimuli had been administered in quiet, a further comparison was undertaken to verify the effect of adding a competitor story. It was important to determine whether the competitor had had the intended effect of distracting the children, thus making it more difficult to complete the target task. All the bilingual and monolingual children from the present study who were tested in French, as well as the additional third group of French-speaking children who had performed the task in quiet were compared in a repeated measures ANOVA with group (administration with competitor story vs. in quiet) as the between subject factor and the two target lists as the within subject factor treated as repeated measures. The children who performed the target task with a competitor scored significantly lower than the children who performed the task in quiet (F (1,47) = 23.75, p = 0.00; partial eta squared = 0.34). Therefore, the comprehension accuracy of the targets was negatively affected when a competitor was presented concurrently, demonstrating that the addition of distracting discourse did have the intended effect.

In the next set of analyses, we examined the relationship between auditory controlled attention and verbal memory. A series of correlational analyses were conducted between each verbal memory measure (CLPT for verbal working memory and the CNRep for verbal short term memory) in each language and each condition of the auditory controlled attention task (FF, EE, FE, EF). These results are reported in Table 3. There was no significant correlation between verbal short-term memory as measured by the CNRep and the auditory controlled attention task for any group in either language. We now turn to the verbal working memory measures as measured by the CLPT in each language. In English, there were no significant correlations between the CLPT and the auditory controlled attention task for any condition for either the English monolingual group or the bilingual children. However, we found significant correlations between the CLPT in French and accuracy on the French intralingual condition (FF) of the auditory controlled attention task for both the French monolingual and bilingual groups (French monolinguals: $r = .60$, $p = .02$; Bilinguals: $r = .62$, $p = .02$). For the French monolingual group, but not the bilingual group, there was also a significant correlation between the CLPT in French and accuracy on the interlingual condition (FE) of the auditory controlled attention task ($r = .73$, $p = .002$).

Given the significant correlations above, we performed a median split of the French verbal working memory scores, in order to directly contrast the effect of working memory and bilingualism. This resulted in two groups of children; those with high verbal memory scores and a second group with low scores. There were 7 French monolingual children and 9 Bilingual children in the high verbal working memory group, leaving 8 French monolingual children and 6 bilingual children in the low verbal working memory group. The means and standard deviations on the auditory controlled attention task by verbal working memory group are shown in Table 4. A repeated measures ANOVA with group (low vs. high working memory) as the between subjects factor and auditory controlled attention as the within subject factor was performed. There was a significant effect of group (F (1, 27) = 15.63, *p* = .001; partial eta squared = 0.37), such that children with high verbal working memories were more accurate than children with low verbal working memories on the auditory controlled attention task. There was also a significant within group effect of the story (*F* (1,27) = 5.33, *p* = .03; partial eta squared = 0.17), such that all children scored lower on the FF condition relative to the FE condition. Inspection of individual data revealed that six children in the low verbal working memory group received a higher score on the French intralingual condition as compared to the interlingual one. Interestingly, all three of the bilingual children who had recalled detailed information from the competitor story were in the high verbal working memory group. Ten of 16 children in the high verbal working memory group received a higher score on the French intralingual condition. Therefore, more children with low verbal working memories were negatively affected by the intralingual condition.

Discussion

The main goal of the present study was to compare the performance of bilingual and monolingual children on a task of controlled attention in the auditory verbal domain. Specifically, we wanted to simulate the everyday experience of a bilingual child who listens and attempts to comprehend speech in one language in the face of competition in the form of meaningful speech from the other language. It is practice in this very task of attending to one language while ignoring the other that has been given as the explanation for the more generalized bilingual advantage in nonverbal tasks of controlled attention (Bialystok, 1999). A second aim of this study was to explore the relationship between verbal memory and auditory controlled attention. This study provided several novel observations from a single experimental design; thus, it would be helpful to summarize each before attempting an interpretation of these results:

- Bilingual children were AS successful as monolingual children in ignoring the competing story and attending to the target sentence comprehension task.
- The French intralingual condition was more challenging than the French interlingual condition for all children who completed the task in French.
- Further analyses, including testing in English, showed that the bilingual children, as a group, had the greatest accuracy when the targets were in French and the competing story was in English.
- The only positive correlation between any verbal memory measure and auditory controlled attention was for working memory (CLPT)

in French. For both the bilingual and French monolingual group, there was a significant and positive correlation between the French CLPT and the French intralingual condition. Additionally, for the French monolingual group, there was a significant correlation between the French CLPT and the French interlingual condition.

- Children with higher verbal working memory scores in French, regardless of bilingualism, were more accurate on the auditory controlled attention task in French, than those with low verbal working memory scores.

The main purpose of the study was to explore the ability of bilingual children to focus their attention on a comprehension task in one language while ignoring the other language. Therefore, a discussion of the interlingual conditions will be presented first. The fact that bilingual children were not any more distracted than the monolingual children by the presentation of a competing story presented in the other language is in line with the hypothesis that they can successfully ignore simultaneously presented distracting information in the other language. Even though, statistically, the groups are equivalent, it can be argued that the bilingual children are actually more successful given that for the monolingual children, there is no need to actively ignore the other language, since it is not meaningful to them. The fact that the bilingual children were as successful as the monolingual children in ignoring simultaneously presented information in the other language may indicate that they were more capable of controlling their attention. Further evidence for the relatively greater success of the bilingual children is that three of them were able to accurately recall detailed information from the competitor in the absence of further decreasing accuracy scores on the target task. That is, these three children actually simultaneously and successfully processed two competing sources of information in different languages.

Our results are in stark contrast to previous research showing that bilingual children make more errors when compared to monolingual English speakers on an auditory verbal task with competing background noise (Nelson et al., 2005). The main and most important difference between the bilingual children in this study and those of Nelson et al. (2005) is the amount of exposure to the English language. The children in this study were simultaneous bilinguals who had been equally exposed to English and French from birth, while those in the Nelson et al. (2005) study were school-age children with an average of only one to two years of exposure to English. Perhaps, when children are equally proficient in their two languages and thus have had extensive practice listening to one language and ignoring the other, they are no more distracted by the competing language than are their monolingual peers. It is also important to note that the lack of a group effect of the competitor story was not due to the story not functioning as a distracter. Recall that when compared to a group of age-matched children who completed the task in quiet, the children in this study had significantly lower accuracy scores on the comprehension of the targets. This finding demonstrates that the presence of competing discourse rendered attending to the comprehension of the target sentences more challenging. Therefore, the auditory controlled attention task was in fact effective in creating enough of a distraction such that it taxed the children and caused them to make more errors on the target sentence comprehension task.

The other two major differences between our study and that of Nelson et al. (2005) are that we used *meaningful* competing discourse and the target task was a *sentence*, not word level comprehension task. Tun et al. (2002) found that the effect of executive control was mediated by the nature of the listening conditions. When targets were heard with a nonmeaningful distracter, executive control predicted performance only marginally, however when targets were heard with meaningful distracters, executive control was a significant predictor. This finding suggests that in order to perform the auditory controlled attention task in this study, children had to recruit controlled attention. Furthermore, Tun et al. (2002) found that verbal ability contributed significantly to recall performance for words only in quiet and with nonmeaningful speech. Given that our task was one completed with a competitor and with meaningful speech, it was crucial that the children in this study have equivalent verbal abilities. Taken together, the findings from such previous research help to explain the discrepant performance of the bilingual children in our study and those in the Nelson et al. (2005) one. The bilingual children in this study were simultaneous bilinguals with equal facility in the two languages and with language skills comparable to those of their monolingual peers in each language. Furthermore, the contextual information in the form of support from other words in the sentence available in our comprehension task probably facilitated performance in the face of competing meaningful discourse.

A second finding in our study was that, importantly, performance deteriorated when the competitor and targets were in the same language and this was true for both the French monolingual and the bilingual groups (though this effect was asymmetrical in that it was seen only when children were tested with French targets, not with English targets). In fact, we would not expect performance to be facilitated in the intralingual condition; it should be more difficult, as the option of turning one language off is not present and other attentional means need to be recruited to ignore the distracting story. For all children, this condition made controlling attention more challenging than the interlingual condition. It may very well be that the interlingual and intralingual conditions pose different attentional challenges. Not only is the language of the target and competitor the same in the intralingual condition but so is the speaker; that is the same speaker was used for the targets and the distracter. Taken together, the findings from the French monolingual and the bilingual groups are in line with those from bilingual adults showing that performance was better when the target and competitor were in different languages as opposed to when they were in the *same* language (Lew & Jerger, 1991). Lew and Jerger (1991) argued that the intralingual condition was more challenging because linguistic interference affected sentence identification performance over and above what could be accounted for by acoustic masking.

The more detailed analyses of the performance of the bilingual children as a group showed that they were differentially affected across the different conditions according to the language of the targets and that of the competitor.

Whenever the targets were presented in French, their performance was superior to when they completed the target task in English. The greatest difference was observed between the French interlingual and English intralingual conditions. First, this finding points to further evidence that the intralingual conditions were unusually taxing and it also indicates that the bilingual children were more tuned into French and as such both showed better performance overall on French targets than English, and also were less easily distracted when the competitor was in English. One explanation for these findings is that, despite careful measures taken to ensure that the bilingual children were equally proficient in their two languages, they still had slightly greater facility in French. In fact, when we examine the raw scores of the bilingual children, 13 of the 14 children who completed the auditory controlled attention task in both languages did better when the target task was in French than when it was in English and eight received their highest score in the French interlingual condition.

Although statistically speaking, the bilingual children had equivalent scores in French and English on receptive vocabulary, CNRep, and CLPT, their raw scores were all a little higher in French than in English for all three measures of verbal ability. Therefore, it is a likely possibility that the bilingual children in this study were slightly more dominant in French; another way of putting it is that they were more or differently experienced in listening to French despite the careful documentation of their exposure levels as being equivalent in French and English. A verbal processing task such as the one used in this study may be particularly sensitive to determining relatively greater proficiency in one language versus the other perhaps because it may tax attentional resources to a greater extent than the CLPT or CNRep do. In our auditory controlled attention task, children are presented with simultaneous, meaningful, and competing information in the same or different languages. This is not the case for either the CLPT or the CNRep. Furthermore, the bilingual children, relative to themselves, seem to be able to control their attention most effectively when the target task is in French and the competitor is in English.

Turning now to the second major purpose of our study, the relationship between verbal memory and auditory controlled attention, we found a strong correlation between verbal working memory (CLPT), in French and auditory controlled attention. No such relationship was found for English and there was also no relationship between verbal short term memory (as measured by CNRep) and auditory controlled attention. Recall that both the French monolingual children and the bilingual children with higher verbal working memory scores received higher accuracy scores in the French intralingual condition, which was in fact more challenging than the French interlingual condition, for all children who completed the task in French. Before turning to a possible explanation for this correlation, it is important to note that these findings provide further evidence that the CLPT and CNRep do in fact measure different abilities, a finding in line with previous research (e.g. Engel, Santos, & Gathercole, 2008; Willis & Gathercole, 2001 among others). For example, Willis & Gathercole (2001) found that CNRep was associated with sentence repetition but not sentence comprehension. The target task in our study was also a sentence comprehension task and we also did not find a relationship with verbal short-term memory as measured by CNRep.

We now turn our attention to the correlation between verbal working memory and our auditory controlled attention task, which demonstrates that this task was cognitively demanding for the children. Recall that the French intralingual condition was particularly demanding as evidenced by a within group difference with the French interlingual condition. The significant positive correlation between the French intralingual condition and the French CLPT indicates that children who completed the task in French had to recruit greater working memory resources to complete this condition. Furthermore, the significant correlation indicates that the two tasks (CLPT and auditory controlled attention) may make similar, although not identical (see above), cognitive demands. In both cases, two sources of verbal information must be processed for successful completion of the tasks. Finally, for the French monolingual children, there was also a significant correlation between the CLPT and the French interlingual condition. This differential effect between the French monolingual children and the bilingual ones indicates that for the French monolinguals processing was more effortful than for the bilinguals in the French interlingual condition. This finding provides further support for the statement made earlier that the bilingual children were, in fact, more successful in the French interlingual condition. It may be that due to daily practice listening to French and ignoring English, bilingual children do not need to recruit working memory to the same degree as the French monolinguals to successfully complete the auditory controlled attention task.

At first glance, the difference between the relationships of the English and French versions of the CLPT with auditory controlled attention seems puzzling. However, Gutierrez-Clellen, Calderon, and Ellis Weismer (2004) also found similar results. In Spanish/English bilingual children, those with high Spanish CLPT scores were less susceptible to interference during a Spanish dual processing task, whereas the same relationship was not replicated for English. This is in line with our finding that for children who completed the task in French, those with higher CLPT scores were less distracted by the presence of the background story than those with lower CLPT scores. Our findings, along with those from Gutierrez-Clellen et al. (2004), suggest that performance on verbal working memory tasks is not *independent* of the language spoken. That is, due to inherent differences between languages, it may not be feasible to construct verbal working memory tasks that are comparable across the two languages. It is not surprising that the French and English languages are different; therefore it is highly likely that the verbal working memory tasks in French and English may have differed in level of difficulty. An examination of the CLPT in French shows that the sentences ranged from 4 to 5 words and 5 to 9 syllables in length, whereas the English CLPT sentences were always 3 words long and ranged from 3 to 5 syllables in length. This difference reflects the nature of French which does not allow for the statements to be as short as they are in English due to the obligatory presence of articles. The same has been discussed for Spanish by Gutierrez-

Clellen et al. (2004) and for Icelandic by Elin Thordardottir (2008b). Therefore, on average, children completing the CLPT in French had to process longer sentences and recall the final word at the end of a longer string of words and syllables; this may have increased the processing demands of the task and thus made the relationship with the sentence level comprehension task of auditory controlled attention tighter.

Another relevant difference, for this study, is that the properties of individual languages pose a unique set of problems for the development of that language (Slobin, 1985). One specific example from early work done comparing English and French is in the acquisition of the past tense showing that it is not until the age of six that French-speaking children use the past tense for verbs with both perfective and imperfective aspect; whereas this occurs as early as at 29 months in English-speaking children (Bronckart & Sinclair, 1973; Smith, 1980). This latter example is simply meant to demonstrate that the development of French and English are different. Another more recent example is given by Elin Thordardottir (2005) who found that similar language sampling procedures in preschool English and French monolingual children yielded quantitative differences in MLU and total number of different words (TDW). MLUs in morphemes were longer in French but vocabularies more constrained than in English. Therefore, French speaking children expressed themselves by using longer utterances, as counted in words and grammatical morphemes, than English speaking children of the same age. The children in the current study were 5-year olds still in the process of acquiring the morphosyntax of French and perhaps needed to recruit greater attentional resources for completing the task in French. That is, at this age, there may be a closer relationship between verbal working memory in French and morphosyntactic comprehension than there is for English.

Given that there was a positive correlation between the French verbal working memory task and the auditory controlled attention task in French, we wanted to directly contrast the effect of bilingualism and verbal working memory. Therefore, we split the groups according to verbal working memory capacity and re-analyzed performance on the auditory controlled attention task. Children with higher verbal working memory scores in French were also more accurate on the target sentence comprehension task in French. This finding suggests that differences in working memory capacity, not bilingualism, are related to differences in the ability to control attention. That is, the presence of competing meaningful discourse limits the attentional resources available for completing a target task in the same modality in children with lower working memory capacities. The relationship between background noise during speech perception and working memory has been investigated in adults. Surprenant (1999) found that the addition of noise caused difficulty in encoding the stimulus words and added a second task for the subject to perform along with the memory task. The group of undergraduate university students in that study, therefore, had more difficulty recalling syllables under a noisier condition. Conway, Cowan, and Bunting (2001) set out to explain why some individuals, but not all, experience the cocktail party effect (recalling one's own name when it is presented in an unattended auditory channel). They tested forty undergraduate students, half of whom had high working memory capacity and the other half had low working memory capacity, on an auditory selective attention task. They had to shadow a word presented to the right ear while ignoring a message presented to the left ear; the subject's first name was inserted intermittently into the irrelevant message. Conway et al. (2001) found that 65% of the participants with low working memory span recalled their name in the unattended message as compared to 20% of the participants with high working memory capacity. Those with low working memory capacities also had more difficulty performing the shadowing task, as evidenced by a greater number of errors; therefore, the presentation of their name seemed to be distracting. The authors concluded that working memory determines success on selective attention tasks.

This study makes a novel and unique contribution to our understanding of controlled attention in bilingual children as well as the relationship between this control and working memory. It is the first study of its kind in simultaneous bilingual children to simulate their real-world experience and demonstrates that they can be as successful as their monolingual peers in ignoring the irrelevant language despite the fact that it is meaningful to them. In fact, as stated and discussed earlier, it can be argued that the bilingual children are in fact more successful because the other language is meaningful and because they do not need to recruit working memory to the same extent as the French monolingual children when completing the interlingual condition. Furthermore, only three children were able to complete the auditory controlled attention task with high scores and still recall a significant amount of detail from the competing story; they were all in the bilingual group. This finding points to the *possibility* that simultaneous bilingual children can process information in two languages at the same time and with high accuracy.

A second important finding is that verbal working memory capacity determines the ability of young children to control their attention. This finding is in line with much previous research in both children and adults showing that working memory capacity and controlled attention are highly related constructs and that individuals with better working memory scores more effectively control their attention (Barrett, Tugade, & Engle, 2004; Engle, Kane, & Tuholski, 1999; Gerstadt, Hong, & Diamond, 1994; Miyake & Shah, 1999; Roncandin, Pascual-Leone, Rich, & Dennis, 2007; Rosen & Engle, 1997). In fact, it can be argued that working memory capacity is a stronger predictor than bilingualism in determining whether children will successfully resist interference. Even though bilingual children are well practiced in the act of ignoring one language while attending to the target language, they are not any more accurate than the monolingual children. When we take into consideration the role of working memory capacity, we see clearly that those children with higher working memory capacities, irrespective of bilingualism, are MORE able to control their attention than those with lower working memory capacities.

The findings from this study are only preliminary, particularly due to the differential effects between French and English. Therefore future studies with larger groups of children and those speaking a variety of languages are needed. One implication is that it is pertinent to better understand the relationship between bilingualism, working memory, and controlled attention in the auditory modality. One prediction is that bilingualism and working memory make independent contributions to controlled attention. Alternatively, it is possible that the ability to resist interference is in fact mediated by working memory and that any observed variance in controlled attention may in fact reflect the influence of working memory and not bilingualism. Work is currently underway in our lab to help tease apart the role of working memory versus bilingualism in success on resistance to interference on auditory verbal tasks. A second important implication is that a task such as the one in this study may be useful as a research and clinical tool in distinguishing bilingual children with normal language skills from those with language disorders. The findings from this study clearly show that typically developing simultaneous bilingual children with equal facility in their two languages are no less accurate than their monolingual peers on a sentence comprehension task in the presence of distracting discourse in the other language. In our lab we are currently looking at the effect on controlled attention of unbalanced exposure to the two languages, as well as the effect of language impairment, on the bilingual child's ability to control attention. In summary, knowledge of the independent contributions that bilingualism and working memory make to the neurocognitive profile of executive control has important practical and clinical implications by providing more specific targets for early intervention in at-risk children who are growing up in bilingual environments.

Tables

Table 1.
Participant characteristics, background and language measures, as well as verbal memory measures showing means and (SDs) for monolingual English-speaking children (EML), bilingual children (BL) and monolingual French-speaking children (FML)

	EML	**BL**	**FML**
Background measures			
Age in months	59.5 (4.4)	58.7 (4.2)	59.4 (4.9)
Gender	6 M, 9 F	6 M, 9 F	5 M, 10 F
Leiter-R	105.5 (11.6)	107.6 (13.4)	105.4 (13.2)
Maternal ed.	16.8 (2.7)	17.9 (2.7)	15.9 (2.2)
French digit span	---	6.3 (2.1)	5.9 (2.6)
English digit span	5.9 (1.7)	6.1 (1.2)	---
EVIP	---	106.3 (14.1)	109.5 (16.7)
PPVT	111.3 (13.1)	100.1 (17.97)	---
CELF-P	10.2 (2.2) (N=12)	9.6 (3.4) (N=13)	---
NEEL 7		3.8(1.6) (N=9)	4.4(1.0) (N=9)
Verbal Memory Measures (reported as percentages)			
Fr Nonword repetition	---	0.91 (0.04)	0.87 (0.05)
Eng Nonword repetition	0.91 (0.07)	0.86 (0.18)	---
CLPT – French	---	0.38 (0.10)	0.34 (0.14)
CLPT – English	0.36 (.09)	0.29 (0.17)	---

Note:
EVIP, CELF-P scores are standard scores
NEEL 7 is a raw score out of 6
Leiter-R scores are standard scores for Brief IQ
Maternal education is reported in years of school completed including elementary school and all subsequent levels.

Table 2.
Auditory controlled attention means and standard deviations by each language group in each of the inter- and intra-lingual conditions tested. The maximum score possible for each condition is 18.

Note:
FF: French intralingual condition (French targets, French story)
FE: French interlingual condition (French targets, English story)
EE: English intralingual condition (English targets, English story)
EF: English interlingual condition (English targets, French story)

Condition: **Group:**	**FE**	**FF**	**EE**	**EF**
FML	11.7(2.8)	11.2(3.8)	N/A	N/A
BL	12.0 (2.0)	9.7(3.8)	9.1(2.4)	8.5(2.8)
EML	N/A	N/A	10.0(3.1)	10.1(2.9

FML: French monolingual group
BL: Bilingual group
EML: English monolingual group

Table 3.
Correlation matrix for auditory controlled attention task and verbal memory measures. Significant correlations are shown in bold.

Note:

Aud CA FF:	Auditory controlled attention French intralingual condition
Aud CA FE:	Auditory controlled attention French interlingual condition
Aud CA EE:	Auditory controlled attention English intralingual condition
Aud CA EF:	Auditory controlled attention English interlingual condition
VWM F:	Verbal working memory in French
VWM E:	Verbal working memory in English
VSTM F:	Verbal short term memory in French
VSTM E:	Verbal short term memory in English

	VWM F	**VWM E**	**VSTM F**	**VSTM E**
Aud CA FF				
Monolingual	**0.60**	N/A	0.40	N/A
Bilingual	**0.62**	0.47	0.53	0.42
Aud CA FE				
Monolingual	**0.73**	N/A	0.26	N/A
Bilingual	0.51	0.34	0.39	0.13
Aud CA EE				
Monolingual	N/A	-0.28	N/A	0.14
Bilingual	0.46	0.08	0.09	0.02
Aud CA EF				
Monolingual	N/A	-0.15	N/A	0.34
Bilingual	0.42	0.28	0.31	-0.14

Table 4.
Means and standard deviations (SD) on the French auditory controlled attention tested in conditions FE (French targets, English story) and FF (French targets, French story), for groups of children with high vs. low verbal working memory (CLPT scores) in French

	High CLPT Group	**Low CLPT Group**
Auditory CA – FE	13.1 (2.1)	10.4 (1.9)
Auditory CA – FF	12.3 (2.7)	8.5 (3.9)

Preface to third manuscript

The previous two manuscripts investigated the performance of typically developing bilingual and monolingual preschool-age children on visual and auditory controlled attention. It was found that when children were equated on visual and verbal working memory and had similar language skills in each language, there was no difference between groups on controlled attention in either modality. In the next and final study, we wanted to know how bilingual children with SLI compare to their typically developing bilingual peers on the same measures of visual and auditory controlled attention. Given the variable findings about visual processing problems in monolingual children with SLI, the current study will add to the body of literature on this subject in bilingual children with SLI. It will also further our understanding of the verbal processing deficits in bilingual children with SLI.

<u>Resisting interference: a preliminary study on the effects of biligualism and language impairment</u>

Mahchid Namazi and Elin Thordardottir

Abstract

In the third and final study, we extended the objectives of the first two studies to bilingual children with Specific Language Impairment. Specifically, we wanted to know how bilingual children with SLI compared to age, nonverbal IQ, and level of bilingualism matched peers on visual and auditory controlled attention. Previous research with monolingual children with SLI has shown that in addition to their significant language and verbal working memory deficits, they also have difficulties with nonverbal cognition (e.g. Johnston & Ellis-Weismer, 1983). The research in bilingual children with SLI is in its infancy and has tended to focus on morphosyntactic deficits (e.g. Paradis, Crago, Genesee, & Rice, 2003. We tested 8 bilingual children with SLI (unbalanced exposure to French and English), 8 level of bilingualism matched peers, and 8 children with balanced bilingual exposure and typical development. All children were given the same tasks as in study one and two, as well as having their language thoroughly assessed. All three groups performed similarly on visuospatial memory and visually controlled attention despite significant differences in verbal short-term and verbal working memory. On the auditory controlled attention measure, the bilingual children with SLI did significantly less well than the balanced bilingual children but similarly to their control group. The results suggest a cumulative

effect of unbalanced bilingualism and SLI. Furthermore, the relationship found between visual memory and visual controlled attention in study one for balanced bilingual children was not present in the two groups of children with unbalanced exposure.

Introduction

Specific Language Impairment has been a topic of debate among researchers from a wide variety of disciplines for over 40 years (see Leonard, 1998 and Johnston, 1988 for reviews). The findings of the language deficits in these children are heterogeneous and evidence correlates language comprehension deficits with deficiencies in working memory (Gaulin & Campbell 1994; Ellis Weismer, Evans, & Hesketh 1999; Gathercole & Baddeley 1990a; Montgomery 1995a). Children with SLI are traditionally described as having a specific deficit in language function with age-appropriate scores on non-verbal intelligence tests, normal peripheral hearing, and normal social-emotional development, in the absence of evidence of frank neurological dysfunction. This exclusionary definition was first proposed by the 1960 Institute on Childhood Aphasia (Johnston, 1988). Since then, research has endeavoured to explicate the nature, character, and cause of SLI. Ample evidence now exists that, in addition to language deficits, monolingual children with SLI also have deficits in working memory, attention, symbolic play, perception, visuospatial skills, and reasoning (e.g. Johnston & Ellis Weismer, 1983; Montgomery, 2000; Marton & Schwartz, 2003; Hoffman & Gillam, 2004; Schul, Stiles, Wulfeck, & Townsend, 2004). However, evidence is also beginning to accumulate that these children, in fact, have normal visual memory and attention skills (Archibald & Gathercole, 2006; Spaulding et al., 2008). Nevertheless by definition, the nonlinguistic deficits have to be milder than the language deficit, and such that they do not merit a clinical diagnosis of their own. Thus, only the language deficit can be of sufficient severity to be in a diagnosable range of clinical tests. At issue is whether the subtle nonlinguistic processing deficits observed contribute to or mediate the evident language difficulties in children with SLI.

On the other end of the spectrum, research with typically developing bilingual children with equal proficiency in their two languages has revealed cognitive advantages in nonverbal measures of controlled attention (Bialystok, 1999). Tasks of controlled attention require the suppression of irrelevant information in order to successfully solve the problem. This enhanced ability has been attributed to the fact that bilingual children are well-practiced in attending to one language while ignoring the non-relevant one; over time, this translates into a domain-general advantage in controlled attention. It is not yet known how bilingual children with language impairment (LI) would perform on nonverbal measures of controlled attention. Research with bilingual children with SLI has focused primarily on identifying linguistic deficits as compared to their monolingual peers. Research to date has indicated that bilingual children with SLI make similar morphosyntactic errors as their monolingual and bilingual counterparts and that bilingualism does not seem to exacerbate the language deficit, at least in the specific area of morphosyntax (Westman, Korkman, Mickos, & Byring, 2008; Paradis, Crago, Genesee, & Rice, 2003; Paradis, Crago, & Genesee, 2005). It has also been shown that bilingual children with LI follow the same developmental sequence as those without language impairment (Salameh, Hakansson, & Nettlebladt, 2004). However, at least one published study has shown that, after controlling for SES, exposure to a second language increased both the risk and severity of language impairment (Cheuk, Wong, & Leung, 2005). Interestingly, even in children with significant cognitive deficits in addition to language impairment, such as in children with Down Syndrome (DS), who grow up in bilingual environments, bilingualism did not lead to an exacerbation of the linguistic deficits when compared to monolingual children with DS (Kay-Raining Bird et al., 2005). Although there is evidence that language impairment in bilingual children can be both under- and over-diagnosed (Salameh, Nettlebladt, Hakansson, & Gullberg, 2002), with the exception of a single study (Cheuk et al., 2005), there is no evidence that the combination of bilingualism and language impairment is detrimental.

Despite the dearth of research about nonverbal abilities and controlled attention, more specifically, in bilingual children with language impairment, recent studies in monolingual children with SLI have shown that they have difficulties suppressing irrelevant information during *verbal* tasks (Lum & Bavin, 2007; Hoffman & Gillman, 2004; Marton & Schwartz, 2003; Montgomery, 2000). Recall that some evidence has shown that typically developing *balanced* bilingual children actually excel at tasks requiring the suppression of irrelevant information both in the verbal and nonverbal domains (Bialystok, 1999). Research comparing the performance of monolingual children with language impairment (LI) on several measures of linguistic and nonlinguistic performance with bilingual children without LI has shown that the former perform less well on both types of tasks (Windsor, Kohnert, Loxtercamp, & Kan, 2008; Kohnert, Windsor, & Ebert, 2009). Furthermore, children with LI performed equivalently to bilingual children not equally proficient in both languages on some verbal tasks such as listening span (Kohnert et al., 2009).

In two previous studies (Namazi & Elin Thordardottir, submitted a & b), we found that typically developing monolingual and simultaneous bilingual children with equivalent exposure to French and English from birth performed similarly on tasks of controlled attention in the visual as well as auditory domains. The controlled attention task in the visual modality was the Simon task, while the auditory controlled attention task consisted of a computerized sentence comprehension task in the presence of meaningful competing speech. We also found that performance on the visual controlled attention task correlated significantly with visuospatial memory and auditory controlled attention correlated with verbal working memory (as measured by the Competing Language Processing Task, CLPT), but not with verbal short-term memory (as measured by nonword repetition). However, in monolingual children with SLI, deficits in verbal short-term memory have been shown to be associated with poor performance in the comprehension and processing of grammar (Gathercole & Baddeley, 1993; Gathercole & Baddeley, 1990). Montgomery (1995b) was one of the first to find a positive correlation between nonword repetition and sentence comprehension abilities in monolingual children with SLI. Correlations have also been found in the SLI literature between receptive language abilities and verbal working memory as measured by the CLPT (Gaulin & Campbell, 1994), a modified version of the listening span task (Daneman & Carpenter, 1980). Gaulin and Campbell (1994) found strong correlations between word recall and receptive-language abilities. Ellis-Weismer, Evans, and Hesketh (1999) found significant correlations between language comprehension abilities and the CLPT (number of words recalled) for a group of young school-age normal children (ages 5-9 years).

It is now evident that children with SLI have more trouble with verbal tasks presented under 'stressful' processing conditions (at fast rates, for example) (e.g. Elin Thordardottir, 2008; Ellis Weismer 1996; Spaulding et al., 2008). Ellis Weismer (1996) had children complete the CLPT and a grammatical morpheme learning task, where morphemes were embedded in short simple sentences presented at normal, fast, and slow rates. The children with SLI produced fewer grammatical morphemes in the fast rate condition as compared to their age-matched peers. Similarly, Elin Thordardottir (2008) showed that English-speaking children with SLI produced a higher rate of morphological errors in narration and expository discourse than in conversation; that is, the error rate increased significantly in more demanding contexts. The children with SLI had significantly lower scores in nonword repetition and on the CLPT than their normal-language controls. Montgomery (1995b) examined the relationship between verbal (phonological) short-term memory and sentence comprehension in a group of children with SLI and a language-matched group of younger children with normal language. The sentence comprehension task consisted of two sets of sentences matched for syntactic complexity and semantic content, one set of "long" sentences and one set of "short" sentences. For the long sentences, the children with SLI comprehended fewer sentences relative to their language-matched controls; a positive significant correlation was also found between verbal short-term memory (as measured by nonword repetition, NWR) and sentence comprehension. This review highlights some studies showing that aspects of language are dependent on available processing resources and that in monolingual children with SLI, linguistic breakdowns have been shown to be related to limitations in processing capacity.

Both verbal working memory and verbal short-term memory have also been investigated in typically developing bilingual children (e.g. Girbau & Schwartz, 2008; Kohnert, Windsor, & Yim, 2006; Gutierrez-Clellen, Calderon, & Ellis-Weismer, 2006). The school-age sequential bilingual learners whom Kohnert and Windsor have studied began learning a single language at birth and acquired a second one sometime later in childhood, usually at around age 5. For example, Kohnert, Windsor, and Yim (2006) compared the performance in English on the CLPT and NWR of three groups of children: monolingual children with LI, typically developing monolingual children, and typically developing bilingual children proficient in Spanish and English. The bilingual children were 10 years old and had a range of 4 to 8 years of experience with English as a second language. On both measures, performance of the monolingual children was best, followed by that of the bilinguals, with the children with LI scoring the lowest. The children in this study were only tested in English, however, and it is likely that the bilinguals did not do as well as the monolinguals because they had not yet achieved a similar level of proficiency in English. Conversely, Gutierrez-Clellen et al. (2006) looked at the performance of fluent sequential Spanish-

English bilingual children on two different measures of verbal working memory (including the CLPT) in Spanish and in English. They also included two groups of unbalanced bilingual children, one more dominant in Spanish and the other more dominant in English. They found no difference on the CLPT between the fluent bilingual children and the Spanish-dominant ones on the Spanish CLPT; however there was a significant difference between the bilingual children and the English-dominant children, with the latter performing slightly better on the English CLPT. Finally, Girbau and Schwartz (2008) investigated verbal short-term memory in Spanish (as measured by nonword repetition) in school-age sequential Spanish-English bilingual children with and without SLI. The typically developing children were less proficient in English than in Spanish, therefore they were unbalanced bilingual children. The children with SLI had lower than average proficiency in both languages and had significantly lower nonword repetition scores than the typically developing bilingual children. Furthermore, performance on the nonword repetition task was highly correlated with auditory language comprehension skills in Spanish in all children. The above review demonstrates that in bilingual children with and without LI, performance on verbal memory measures is highly variable and dependent on proficiency in the language being tested.

We could not locate any studies that had looked at the nonlinguistic performance of bilingual children with LI compared to bilingual children without LI. However, one study has investigated the nonlinguistic performance of school-age monolingual children with LI to two groups of children: typically developing fluent bilinguals and English monolinguals (Windsor, Kohnert, Loxtercamp, & Kan, 2008). Windsor et al. (2008) compared the performance of the latter three groups of children on seven different nonlinguistic tasks in the *visual* modality, assessing abilities ranging from low-level to higher order cognition. The tasks included odd-man out (considered the simplest task in which participants identify one of three elements that doesn't belong with the other two), two memory measures (pattern matching and serial memory), number search, simple arithmetic, and two complex visual-spatial processing tasks (mental rotation and form completion). In five of the seven tasks, the monolingual children with LI performed significantly less well than both the bilingual and monolingual groups; there were no significant differences between the latter two groups.

We have seen that monolingual as well as bilingual children with SLI have significant deficits in the verbal domain as compared to typically developing monolingual as well as bilingual children. Some of the published research also indicates that monolingual children with SLI perform less well in the nonlinguistic domain compared to both monolingual and bilingual children without language impairment. To date, the published research shows that bilingual children with SLI make similar linguistic errors in grammatical morphology, have deficits in verbal short-term memory, and there is no conclusive evidence that bilingualism exacerbates or has a cumulative effect on language deficits. Bilingual children with typical language display variable performance on linguistic measures of short-term and working memory depending on the amount of exposure to or level of proficiency in each language. Finally, in the nonverbal domain, typically developing bilingual children have been shown both to excel at controlled attention tasks, and to perform as well as monolingual children on several different measures of nonlinguistic ability.

<u>The current study</u>

The goal of this study was to conduct a preliminary exploration of visual and auditory controlled attention in bilingual children with SLI with equal exposure to their two languages. We wanted to know how young simultaneous bilingual children with SLI compare to their same-age peers on these measures. Second, we were interested in the relationship between our controlled attention measures and visual and verbal memory. Finally, we wanted to extend our previous research with normally developing balanced bilingual and monolingual children (Namazi & Elin Thordardottir, submitted a; b) to bilingual children with SLI. When we first designed the study, our intention had been to include fifteen 5-year old simultaneous bilingual children with SLI who had had equal exposure to French and English from birth. Furthermore, the inclusion of balanced bilingual children with SLI would allow us to make comparisons with the typically developing balanced bilingual children in our two previous studies, allowing us to extend our findings. However, finding a group of balanced bilingual children with SLI proved to be extremely challenging for several possible reasons. In Quebec, the diagnosis of SLI is usually not given until children are five and older. With respect to raising children with language impairment bilingually, we discovered that many parents had made a decision early on to minimize exposure to one of the two languages as soon as their child was displaying language difficulties. A related reason may be that parents had been counseled out of bilingualism once their child was diagnosed as having a language delay. A two and a half year recruitment process yielded 8 French-English bilingual children with SLI within the targeted age range, yet these children had varying levels of exposure to English and French. Therefore, we modified the goals of our study somewhat. In order to allow us to make a fair comparison to an appropriate control group, we included a typically developing age-matched group also with varying levels of exposure matching those of the children with SLI. In order to make fair comparisons between the group with SLI and the typically developing one, it was important to equate them on amount of exposure to each language. The importance of the decision to match in this way is highlighted by the fact that a number of studies (including some reviewed in this introduction) have shown that the difference in language scores between monolingual and bilingual children is related to the children's *relative* amount of exposure to each language; that is, bilingual children receive higher verbal scores in the language of greater exposure (Elin Thordardottir, 2008; Oller, Pearson, Cobo-Lewis, 2007). Additionally, linguistic as well as nonlinguistic processing measures have been correlated with first and second language learning abilities (Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Ellis & Sinclair, 1996; Gathercole & Pickering, 2000; Service, 1992), further underlining the importance of documenting and equating children on balance of language exposure.

As a result, we now had a group of typically developing bilingual children with varying levels of exposure to French and English; we also included a balanced bilingual group thereby allowing us to explore the effects of both level of exposure, as well as language impairment. Including this third group allows us to investigate whether differences observed between the children with SLI and their control group are due to unequal amounts of exposure to each language or due to the language impairment. Previous research looking at the cognitive advantages in bilingualism has been done with balanced bilinguals who use both languages on a regular basis with equal proficiency (Bialystok, 1999; Bialystok & Martin, 2004; Bialystok, Martin, Viswanathan, 2005; Bialystok & Senman, 2004; Bialystok & Shapero, 2005). However, research on the performance of bilingual children on a number of memory measures indicates that the amount of exposure these children have had to each language, and whether their performance in both languages is relatively balanced does influence their results on linguistic memory tasks. It is of interest, therefore, to explore the effects of amount of exposure on controlled attention and memory.

In summary then, we explored verbal working memory, visuospatial memory, and controlled attention in 5-year old typically developing bilingual children with varying amounts of language exposure and those with SLI. We were particularly interested in the effects of language impairment and balance of language exposure on memory and controlled attention. The specific questions we addressed in this study were:

- How do bilingual children with SLI perform compared to bilingual children with NL with comparable levels of bilingual exposure on measures of visual and auditory controlled attention?

- How do the groups with unbalanced exposure compare to a typically developing group with balanced exposure on measures of visual and auditory controlled attention?
- What is the relationship between visuospatial memory and visually controlled attention in these three groups of children?
- What is the relationship between verbal memory and auditory controlled attention in the same three groups of children?

Based on our two previous studies, as well as research showing the relative strength of children with SLI on nonverbal cognition, we predicted that children in all groups would perform similarly on visual controlled attention. With respect to auditory controlled attention, we expected to see an effect of language impairment as well as language exposure, such that the typically developing children with balanced exposure would receive the highest scores followed by those with unbalanced exposure and finally the bilingual children with SLI.

Methods

<u>Participants</u>

Twenty-four children participated in this study. They included three groups as follows: 8 bilingual children with SLI (SLI-b) (mean age 64.25 months; 7 boys, 1 girl) with varying levels of exposure to French and English, 8 bilingual children with typical development (TD-b) (mean age 59.13 months; 6 boys, 2 girls) pairwise matched in language exposure to the SLI-b group, and 8 bilingual children with balanced exposure to French and English (TD-B) (mean age 59 months; 3 boys, 5 girls). A hearing screening at 10 dB HL under headphones at octave frequencies from 500 to 4000 Hz was passed by all children. Reliable results could not be obtained at 500 Hz for some children because testing was not completed in a soundproof booth. The group of 8 children with typical development and unbalanced exposure to French and English (TD-b) was randomly selected from a larger data set (Elin Thordardottir, 2008) by a research assistant. The third group of 8 children (TD-B) was a subset randomly selected from a group of 15 balanced bilingual children who participated in a previous study (Namazi & Elin Thordardottir, submitted b).

The range of exposure to English in the two unbalanced bilingual groups was 25 to 80%. The criterion used in selecting typically developing children who were pairwise matched to the children with SLI for language exposure was to find as close a language exposure match as possible such that the difference in exposure between each pair of children was less than or equal to 10%. Each unbalanced bilingual group comprises 4 children who are more English dominant (exposed to English more than 50% of the time) and 4 who are more French dominant. As reported in Namazi and Elin Thordardottir (submitted a), the range of relative exposure to English and French in the balanced bilingual group (TD-B) was 40 to 60%. A one-way ANOVA revealed that the three groups were matched on age (p = 0.18) and SES (p = 0.71). Furthermore, to be included in the study, all children had to score within normal range (85 to 115) on nonverbal IQ as measured by the Leiter International Peformance Scale-Revised (Roid & Miller, 1997). Although the children with SLI did score within normal range, a one-way ANOVA showed there was a significant difference in nonverbal IQ between the three groups (*F*(2,23) = 13.20, *p*=.0.00). Post-hoc testing revealed that the SLI-b group differed significantly from each of the TD-b (mean difference -20.6, *p* = 0.00) and TD-B (mean difference -23.5, *p* = 0.00) groups. Table 1 shows the means and standard deviations for all three groups on the background measures.

The typically developing children were recruited from local preschools and daycares in the greater Montreal area. Children identified as having SLI were recruited through speech therapy clinics (including private practitioners) in Quebec and Ontario where they had received a speech-language evaluation or were on the waiting list for one due to concerns about their language development. Five of the eight children with SLI were enrolled in speech-language therapy at the time of testing; the three others had received their diagnoses shortly before participation in the study. Three children had a family member diagnosed with dyslexia. To be included in the SLI group, children had to score 1 or more standard deviations below the normal range in their dominant language as compared to monolingual children speaking the same language, on two of the following verbal measures: sentence imitation, MLUm (in morphemes), CELF-P2, PPVT, or the EVIP (descriptions of these tests are provided below). For children in all three groups, patterns of amount, length, and age of exposure to each language, relative proficiency in French and English, medical history, developmental history, and family structure were gathered by completion of a detailed parent questionnaire (Elin Thordardottir, Rothenberg, Rivard & Naves, 2006). Only children who had been exposed to English and French during communicative interactions from before age 3 and had no significant exposure to any other language were included.

Children who met the criteria as outlined above were then seen for further testing. Children were given a test of forward digit span in English and French, a test of visuospatial memory, a test of verbal short-term memory, and a test of verbal working memory. Children's verbal abilities were assessed in each language using formal and informal measures. In French, the Échelle de vocabulaire en images Peabody (EVIP) (Dunn, Thériault-Whalen & Dunn, 1993) was used, while in English, the Clinical Evaluation of Language Fundamentals-Preschool Second Edition (CELF-P2) (Semel, Wiig, & Secord, 2003) and the Peabody Picture Vocabulary Test- Revised (PPVT-III) (Dunn & Dunn, 1997) were used. All children were also given a sentence imitation task (from the CELF-P2 in each language) and participated in a play-based conversation to elicit a language sample for MLUm calculations. The EVIP and PPVT-III are standardized tests of receptive vocabulary in French and English, respectively. The three subtests of the CELF-P2 assess receptive and expressive vocabulary, grammar, and morphosyntax in English. Means and standard deviations on the verbal measures are summarized in Table 2. A series of one-way ANOVAs were completed to compare the group means on the eight language measures. This procedure was chosen over a single MANOVA in order to avoid list-wise deletion, resulting in small Ns that would then significantly reduce the power. The ANOVAs allowed for pairwise deletion so that a participant was used in an individual analysis if he or she had data for that analysis. There was a significant group difference on all verbal measures, as follows: In French, the EVIP ($F(2,23) = 11.90$, $p=0.00$), MLUm ($F(2,20)=4.72$, $p = 0.02$), and sentence imitation ($F(2,22)=11.63$, $p = 0.00$); In English, the PPVT-R ($F(2,23) = 6.77$, $p = 0.00$), the CELF-P2 ($F(2,21) = 6.92$, $p = 0.01$), MLUm ($F(2,22)=3.49$, $p = 0.050$), and sentence imitation ($F(2,23) = 6.31$, $p=0.01$).

For the French measures, post-hoc pairwise comparisons (Tukey's HSD) showed that the TD-B group outperformed both the SLI-b group (t=50.00, $p=0.00$) and the TD-b group (t=27.12, $p=0.04$) on the EVIP as well as on sentence imitation (SLI-b: t=0.48, $p=0.00$; TD-b: t=0.27, $p=0.04$), whereas for French MLUm, the TD-B only did better than the SLI-b group (t=2.19, $p=0.02$). For the English measures, the SLI-b group did more poorly than both other groups on the PPVT (TD-b: t=23.37, $p=0.01$; TD-B: t=23.25, $p=0.01$), on sentence imitation (TD-b: t=0.36, $p=0.01$; TD-B: t=0.32, $p=0.02$), and on the CELF-P2 (TD-b: t=23.5, $p=0.03$; TD-B: t=32.00, $p=0.01$). The post-hoc test was not significant for MLUm in English. Therefore, all verbal measures (except English MLUm) in both French and English did differentiate the SLI-b group from one or the other group. Furthermore, according to the norms published in the standardized test manuals, the scores of the 4 children with SLI who were more English dominant (70 to 80% English) on both standardized measures in English (CELF and PPVT-R) fell 1 or more standard deviations below the range expected for their age compared to monolingual children speaking English. For 3 of the 4 French-dominant children with SLI, their receptive vocabulary scores in French fell 1 or more standard deviations below the range expected for their age compared to monolingual children speaking French. For the remaining child, both his MLUm and sentence imitation score in French (his dominant language) fell more than one standard deviation below norms compared to monolingual children of the same age (Elin Thordardottir et al., submitted).

Procedures

All the children were tested by a native speaker of either English or French, individually in a quiet room at the university, in their daycare, or in their home. Testing was completed in two 2- hour sessions, separated by at least 1 week. The order of testing was counterbalanced across participants. Examiners included the first author for the English testing and a trained research assistant for the French testing. Fifteen children were tested in French first, while 9 children completed the testing first in English.

Memory Measures

The children's verbal working memory was assessed using the Competing Language Processing Task (CLPT) (Gaulin & Campbell, 1994) and a French adaptation by Elin Thordardottir (2006). This test has been reported on in detail in Namazi and Elin Thordardottir (submitted a). The task involves judging the veracity of sets of sentences while memorizing the final word of each sentence. To measure verbal short-term memory in English, the Children's Test of Nonword Repetition (CNRep, Gathercole, Willis, Baddeley, & Emslie, 1994) was used. The corresponding French measure used was a French nonword list developed by Courcy (2000); we will refer to this measure as French NWR. As an additional measure of verbal short-term memory, the children were also given a digit span test in both French and English. To assess visuospatial memory, a modified version of the pattern recall task (Jarrold, Baddeley, & Hewes, 1999) developed by the first author was used. Our version was a computerized task using Sponge Bob figures; the details can be found in Namazi and Elin Thordardardottir (submitted a).

Controlled Attention in the visual domain

The Simon task, used in previous research showing an advantage in controlled attention among bilingual children and adults relative to monolingual peers, was the test of visually controlled attention. The participant's task was to press a red button when a red square appeared on the computer screen, and to press a blue button when a blue square appeared. Congruent and incongruent trials were presented in random order. A congruent trial consisted of a red or blue square appearing on the same side of the screen as its respective button. An incongruent trial consisted of a red or blue square appearing on the opposite side of its respective button. The details of our version of the task are reported in Namazi and Elin Thordardottir (submitted a).

Controlled Attention in the auditory modality

This task was constructed expressly for this study by the first author, the details of which are reported in Namazi & Thordardottir (submitted b). The comprehension stimuli included computerized versions of the Test for Auditory Comprehension of Language-Revised (TACL-R) (Carrow-Woolfolk, 1999) in English and a Quebec French adaptation commonly referred to as “Le Carrow”, which involved standardization for young school-aged children and has been in substantial clinical use (Groupe coopératif en orthophonie - Région Laval, Laurentides, Lanaudière, 1995). The sentences from subtests II and III (morphosyntax and complex sentences) of the TACL-R (French and English) were divided into two lists, in each language, equated for level of difficulty; the odd numbered sentences made up one list and the even numbered sentences made up the other list. This procedure resulted in four lists of 18 sentences, 2 in English and 2 in French. Each of the lists in either language was then paired with a background story in either French or English, resulting in two general conditions: (1) target and competition in the same language ("intralingual" condition: EE: target and competition in English; FF: target and competition in French) and (2) target and competition in different languages ("interlingual" condition: EF: target in English, competition in French; FE: target in French, competition in English). The meaningful auditory distraction (competition), presented simultaneously with the comprehension stimuli, was a story familiar to young children recorded and synthesized by two different female native speakers of English and French. The sentences (target) were on average 10dBA louder than the background story (competition); a +10dB SNR was chosen based on previous research with young bilingual children looking at the effects of typical classroom noise on speech perception (Nelson et al., 2005).

Children were given the following instructions "you will see three pictures at a time on the screen while you listen to sentences. You need to touch the picture on the screen that goes with the sentence you hear. Wait until the sentence is finished before you touch the picture. Someone else will be talking while you are listening to the sentences; don't listen to that person; only listen to the one who's telling you about the pictures." Once the child had responded, the next sentence was made available. All children completed a practice trial of 8 sentences in quiet in order to ensure that they understood the task. At the completion of the task, the child was asked two questions about who and what the story was about; this was done in order to verify story recall despite being told to ignore it. All children completed the sentence comprehension task (target) in each language, while simultaneously listening to each story in each language.

Results

Memory measures

The means and standard deviations on the verbal and visuospatial memory measures are shown in Table 3. Before turning to the analyses of controlled attention, we will report on the visuospatial memory and verbal memory measures which were analyzed by means of a single ANOVA and MANOVA. The group difference on the visuospatial memory measure was tested by means of a one-factor ANOVA which revealed no significant difference between groups ($p = 0.32$). Therefore, the children in the three groups were matched on visuospatial memory as measured by the Pattern Recall task. Group differences on the 6 verbal memory measures were tested by means of a one-way MANOVA due to correlations between the dependent variables (all verbal memory measures) and as a way to guard against inflating Type I error. There were significant group differences on 3 of the 6 verbal memory measures. The results were as follows:

1) French nonword repetition ($F(2,20) = 7.97$, $p = 0.00$; partial eta squared = 0.48); post-hoc pairwise comparisons (Tukey`s HSD) showed that only the TD-B group did better than the SLI-b group ($t = 0.21$, $p = 0.003$); 2) French CLPT ($F(2, 20) = 7.69$, $p = 0.00$; partial eta squared = 0.48), post-hoc testing showed that the TD-B group did better than *both* the SLI-b group ($t = 0.31$, $p = 0.00$) and the TD-b group ($t = 0.22$, $p = 0.04$). In English, the only significant group difference was on the forward digit span, ($F(2, 20) = 6.65$, $p = 0.007$; partial eta squared = 0.44); post-hoc pairwise comparisons (Tukey's HSD) showed that only the TD-B group did better than the SLI-b group ($t = 2.93$, $p = 0.01$). There were no group differences on English nonword repetition ($p=0.21$), the English CLPT ($p = 0.12$), or the French digit span ($p=0.06$).

<u>Controlled attention in the visual domain: the Simon task</u>

Results of the Simon task include accuracy scores and reaction times. The reaction time measures reflect the average reaction time on all correct experimental trials. For the experimental trials, anticipatory responses, defined as those with a reaction time of 200 ms or less, were excluded from the total. To determine whether there were any differences among the three groups on visually controlled attention, two repeated measures ANOVAs were completed, one for accuracy scores (reported as percentages) and one for reaction times in milliseconds. In each case, congruent and incongruent trials were treated as repeated measures. There was no main effect of group for either reaction time ($p = 0.47$) or accuracy ($p = 0.62$). There were no significant within group or interaction effects. Therefore, the three groups of children, irrespective of level of bilingualism or language impairment, performed similarly on the Simon task.

In our previous study using the Simon task to compare typically developing monolingual and balanced bilingual children, we found that performance on this task was related to visuospatial memory scores and not to bilingual or monolingual status (Namazi & Elin Thordardottir, submitted a). Here, we were interested in extending that analysis to bilingual children with and without SLI. Therefore, we performed a median split of the visuospatial memory measures for the group of children with SLI and their control group with unbalanced exposure. This resulted in two groups of children, with 8 ranking high and 7 ranking low on visuospatial memory. There were 3 children with SLI in the high rank group and 5 typically developing controls. We did not include the children with balanced exposure as this analysis had been done elsewhere (Namazi & Thordardottir, submitted b). Here we wanted to know if we would find the same or a different relationship between pattern recall and the Simon task in the case of children with unbalanced exposure with and without SLI. We then conducted two repeated measures ANOVAs, one for accuracy scores and one for reaction times on the Simon task with group (rank high or low on pattern recall) as the between subjects factor and either accuracy or reaction time as the within subject factor with congruent and incongruent trials treated as repeated measures. There were no significant main effects of group, within subject effects, or interaction effects in either ANOVA. Unlike in our previous study, for the children in this study with unbalanced exposure to their two languages, no relationship between performance on the Simon task and visuospatial memory was discernable, possibly due to the nature of the relationship being different in children with unbalanced exposure or reduced power as a result of small sample sizes.

Controlled attention in the auditory modality

Group means and standard deviations of accuracy scores on the auditory controlled attention task are reported in Table 5. The maximum raw accuracy score possible on each list was 18. Where applicable, results will be discussed in terms of interlingual and intralingual conditions where the target is the sentence comprehension task and the competitor is the background story. The language in which the targets were presented will always be listed first followed by the language of the competitor. For example, FE is the French *inter*lingual condition because the targets were presented in French and the competitor was presented in English, whereas FF is the French *intra*lingual condition (targets and competitor are in the same language).

To compare the children's accuracy on auditory controlled attention, a single repeated measures ANOVA was conducted with group (SLI-b, TD-b, TD-B) as the between subject factor and accuracy on the auditory controlled attention task as the dependent variable with language of the competitor treated as a repeated measure. There was a significant main effect of group ($F(1,19) = 6.27$, $p = 0.01$; partial eta squared = 0.41); post-hoc pairwise comparisons (Tukey's HSD) showed that only the TD-B group did better than the SLI-b group ($t=3.70$, $p=0.01$). There were no significant within subject or interaction effects.

Given the significant difference between groups on the auditory controlled attention task and the significant differences in verbal memory abilities as well as nonverbal IQ between groups, two repeated measures ANCOVAs were completed. One treated nonverbal IQ as a covariate while the other treated the verbal memory measures with significant differences between groups (CLPT in French, nonword repetition in French, and English digit span) as covariates. This was done in order to determine whether the significant differences reported above on the verbal memory measures and nonverbal IQ contributed to performance on the auditory controlled attention task. The repeated measures ANCOVA was run with group (SLI-b, TD-b, TD-B) as the between subjects factor and accuracy on the auditory controlled attention task as the dependent variable with language of the competitor treated as a repeated measure. The difference between groups was no longer significant when nonverbal IQ, the French CLPT, the French nonword repetition test, and English digit span were treated as covariates (p = 0.60, p = 0.08, p = 0.10, and p = 0.41 respectively).

Just as in the case of visually controlled attention, in the next and final analysis we were interested in the relationship between auditory controlled attention and verbal memory in each language in the two groups of children with unbalanced exposure. We wanted to extend the findings of our previous study with balanced bilinguals and monolinguals matched on verbal memory (Namazi & Elin Thordardardottir, submitted b) to determine whether a similar or different relationship held for children with and without SLI. In our previous study, we found that in typically developing balanced bilingual children matched to monolinguals on verbal memory, those with high scores on verbal memory performed better than those with low verbal memory scores on the auditory controlled attention task. The two unbalanced groups in this study were also matched on 5 of 6 verbal memory measures; recall that only the French CLPT differentiated the TD-b and SLI-b groups from each other. Furthermore, we already know from the above analysis that there was no effect of language impairment on the auditory controlled attention task as evidenced by the lack of a difference between the two unbalanced groups.

We, therefore, performed a median split on nonword repetition and CLPT in each language, yielding 8 groups of children ranking either high or low on each of the 4 measures. This resulted in the following: 5 children with SLI (and 3 TD-b) in the low French nonword repetition group, 4 children with SLI (and 3 TD-b) in the low French CLPT group, 6 children with SLI (and 2 TD-b) in the low English nonword repetition group, and 6 children with SLI (and 2 TD-b) in the low English CLPT group. We then conducted two repeated measures ANOVAs with group (high or low verbal memory on each of nonword repetition and CLPT in each language) as the between subject factor and accuracy on the controlled attention task as the dependent variable with the language of the competitor treated as a repeated measure. We performed two separate ANOVAs because we were interested in the relationship between verbal memory measures in each language and the auditory controlled attention task in that language. We already knew from our previous study (Namazi & Elin Thordardottir, submitted b) that the relationships were different for the two different languages. For the French auditory controlled attention task, the only significant effect was a main effect of CLPT group (7 children in each group) ($F(1,9) = 13.05$, $p = 0.01$; partial eta squared = 0.59); the children ranking high irrespective of the existence of a language impairment did better on the auditory controlled attention task. There were no other group, within subject, or interaction effects. For the English version of the auditory controlled attention task, there was a single significant effect of nonword repetition group (8 children in each group) ($F(1,12) = 5.62$, $p = 0.03$; partial eta squared = 0.32); again the children ranking high on this measure did better on the auditory controlled attention task. There were no other group, within subject, or interaction effects.

Discussion

The primary goal of this preliminary study was to see how bilingual children with SLI compare to their bilingual same-age peers matched for language exposure on measures of visual and auditory controlled attention. A secondary goal was to investigate the relationship between controlled attention and memory in these populations. Finally, we also looked at the effect of level of language exposure on controlled attention and memory. Due to the small sample sizes, the results of this study are only suggestive and will be interpreted with caution. However, this study represents a first step in exploring controlled attention and memory in bilingual children with SLI as compared to their age-matched and level of bilingualism matched peers. Furthermore, other published studies in bilingual children with SLI using experimental designs have also included small sample sizes of 7, 8, or 10 children (e.g. Paradis, Crago, & Genesee, 2005;

Paradis, Crago, Genesee, Rice, 2003; Salameh, Hakansson, & Nettelbladt, 2004). Therefore the number of children used in our study is not atypical of similar research, which probably speaks to the challenge of recruiting this group of children. Our bilingual children with SLI were selected according to the criteria that they had to score below normal range on formal and/or informal verbal measures in their stronger language as compared to monolingual children speaking the same language. Furthermore, they met the conventional criterion (for children with SLI) of delayed language skills despite normal range cognitive, sensory, and motor abilities. Although we set out to find balanced bilingual children with SLI, this proved to be a very challenging task, therefore half the children were more proficient in English, while the other half were more proficient in French. In order to make fair comparisons with a group of children matched on level of bilingualism, we then did a pairwise match with children from a larger data set, who also were matched in terms of their exposure pattern. Finally, in order to be able to tease apart differences due to language impairment versus those related to level of bilingualism, we included a subset of the balanced bilingual children who had participated in our previous two studies (Namazi & Elin Thordardottir, submitted a & b).

To address the primary goal of our research study, we will first discuss the results from the analyses of visually controlled attention using the Simon task followed by the auditory controlled attention task. To summarize, there were no differences among the three groups on either speed or accuracy on the Simon task. Therefore, neither the existence of a language impairment nor unequal exposure to two languages seemed to change how children performed on visually controlled attention. This is in line with the findings from our previous study (Namazi & Elin Thordardardottir, submitted a) which showed similar performance on the Simon task between balanced bilingual and monolingual groups matched on visuospatial memory. The three groups of children in the current study also performed similarly on visuospatial memory as measured by the pattern recall task. Although our sample sizes were small, therefore limiting the power of our findings, these findings provide some preliminary evidence that in the case of bilingual children with SLI, visuospatial memory and visually controlled attention as measured by the Simon task are unaffected by the presence of a language impairment. This is in contrast to findings with monolingual children with SLI showing slowed visual processing (with short processing intervals) relative to typically developing age-matched controls (Schul et al., 2004).

Importantly, the children in this study, including the ones with SLI had visuospatial memory spans as measured by the pattern recall task that were equivalent to the other two groups despite significant differences in verbal abilities as well as nonverbal IQ. We know from the findings of our previous study (Namazi & Thordardottir, submitted a) that performance on the Simon task correlates significantly with visuospatial memory as measured by the pattern recall task. The bilingual children with SLI in this study actually had better pattern recall scores than those reported in other studies on monolingual children with language impairments (Hick, Botting, & Conti-Ramsden, 2005). For example, monolingual children with SLI in Hick et al.'s (2005) study (who were on average six months younger than the children in this study) received a mean score of 9.8 compared to a mean score of 12.8 for our bilingual children with SLI on a similar pattern recall task (they used different images) using the same scoring procedures. Although the mean score of 14.1 for our balanced bilingual children is almost equivalent to the mean score of 14.4 for the typically developing monolingual children, the bilingual children with SLI in the current study received a score almost identical to a group of *typically* developing monolingual children of the *same age* in Jarold et al. (1999) who had a mean score of 12.6. Therefore, it is likely that the strong visuospatial memory abilities of our children with SLI allowed them to perform as well as the typically developing children on the Simon task. Our results for the bilingual children with SLI are inconsistent, however, with those of Windsor et al. (2008) who found that their monolingual children with language impairment performed less well than typically developing bilingual and monolingual same-age peers on a series of visual processing tasks. Our finding of normal memory and processing for visual information is more in line with others such as Archibald & Gathercole (2006) who have shown that monolingual children with SLI actually performed similarly to their age-matched peers and better than their language-matched peers on visuospatial memory.

We will now turn to the findings from our task of auditory controlled attention. We had originally designed this task (Namazi & Elin Thordardottir, submitted b) in order to assess the ability of balanced bilingual children in dealing with the real-world task of ignoring meaningful speech in one language when engaged in a language comprehension task in the other language. We wanted to extend those findings to bilingual children with SLI and those with unbalanced exposure to their two languages. As reviewed in the introduction, there is some evidence that children with SLI have difficulty processing language under effortful conditions therefore we expected this task to be very challenging for them. We expected that they would do less well than both bilingual groups because this task is in essence a language comprehension task under more demanding conditions. As for the typically developing children with unbalanced exposure, we expected that they too would have more difficulty than the balanced bilinguals when completing the task in their less dominant language and listening to a competitor in the more dominant language, as it may be harder for them to ignore the former language. Secondarily, although this was not a primary goal of our study, in the case of bilingual children with SLI and those with unequal bilingual exposure, this task also has the potential of addressing the issue of subtle linguistic processing deficits or language dominance, respectively if it can differentiate the three groups of children in this study. The inclusion of a balanced bilingual group allowed us to consider and select between these two possibilities.

In this study, group comparisons on the auditory controlled attention revealed that the only significant group difference was between the TD-B and the SLI-b group. Therefore our auditory controlled attention task differentiated the SLI-b group from the group of children with balanced bilingual exposure, but not from the TD-b group. The lack of a difference between the group of children with SLI and their exposure-matched control group suggests that the presence of language impairment in children with unbalanced exposure does not further reduce performance on the auditory controlled attention task. The fact that there is no difference between the TD-b and TD-B groups further suggests that unbalanced bilingual exposure on its own does not affect performance. These findings suggest that there may be a cumulative effect of unbalanced bilingualism and language impairment in the auditory-verbal modality on a language comprehension task completed under increased processing demands. In summary, neither a language impairment nor unbalanced exposure in and of itself is sufficient to reduce performance on the auditory controlled attention task; however, when these conditions co-occur, performance is significantly reduced, resulting in a cumulative effect.

Importantly, unlike in our previous study with typically developing children (Namazi & Elin Thordardottir submitted a), the children in this study were not matched on verbal memory. When we covaried the verbal memory measures on which the children differed, there was no longer any difference between the groups on the auditory controlled attention task. Therefore, it was poor performance, at least in part, on the verbal memory measures that led to detrimental performance on the auditory controlled attention task. Interestingly, nonverbal IQ as measured by the Leiter also explained some of the group difference on the auditory controlled attention task because when this measure was covaried, there was no longer any difference among the three groups of children. These findings are consistent with those of Liss et al. (2001) who also found that in children with developmental language disorders, all of their executive function measures--one of which was controlled attention--correlated with both verbal and nonverbal IQ, whereas for children with Autism, performance was only related to verbal IQ.

Turning now to our next research question, in order to explore the relationship between visually controlled attention and visuospatial memory in the two groups of unbalanced bilinguals, we performed a median split of the pattern recall scores. We knew from the findings in our previous study (Namazi & Elin Thordardottir a) that visuospatial memory (pattern recall) correlated with performance on the Simon task in balanced bilingual and monolingual children. We were surprised to find that in the case of children with unbalanced exposure, when we compared performance on the Simon task using pattern recall scores to split groups, we found no difference between the groups. That is, children with high pattern recall scores were as accurate and as fast on the Simon task as those with low pattern recall scores. This finding is in direct contrast to that found in our previous study comparing balanced bilingual children with monolingual speakers of each language (Namazi & Elin Thordardottir a). The most likely explanation for this is that the small sample sizes and greater variability in performance in the current study (a total of 15 compared to a total of 45 in the previous study) led to a lack of a significant relationship between pattern recall and the Simon task. The other possibility is that the relationship between pattern recall and the Simon task is different as a result of unbalanced exposure to two languages. In order to decide between these possibilities, future studies need to include larger groups of children with unbalanced exposure who are typically developing or who have a language impairment.

To address our final research question, we performed a similar analysis for auditory controlled attention as we had for visually controlled attention. Again we did not include the TD-B group because we already knew from our previous study (Namazi & Elin Thordardardottir, submitted b) that there was a relationship between verbal working memory in French as measured by the French CLPT and the French auditory controlled attention task. Therefore, we wanted to extend those findings to bilingual children with and without SLI. Furthermore, we already knew from the ANCOVA analysis on the auditory controlled attention task that the difference between the SLI-b and TD-B group disappeared once the significantly different verbal memory measures were covaried. Our analysis showed that in the two unbalanced groups, the children with high nonword repetition scores in English were more accurate on auditory controlled attention in English, whereas in French, CLPT performance was related to accuracy on the French version of the task. This finding is partially in line with our previous results for the balanced bilingual children in French (Namazi & Elin Thordardardottir, submitted b). However, the positive relationship between English nonword repetition and the English auditory controlled attention is unique to the SLI-b and TD-b groups.

Taken together, these findings support those from previous research showing links between receptive language/sentence comprehension and either verbal short-term or verbal working memory (e.g. Ellis-Weismer, Evans, &

Hesketh, 1999; Montgomery, 1995b). Montgomery (1995b) reported a positive correlation between nonword repetition and sentence comprehension abilities in English-speaking monolingual children with SLI. Conversely, Ellis-Weismer et al. (1999) found significant correlations between language comprehension abilities and the CLPT in young school-age typically developing children. Therefore, even for monolingual speakers of English, there is no consensus on whether verbal working memory as measured by the CLPT or verbal short-term memory as measured by nonword repetition are more related to receptive language. Perhaps this is a by-product of the inherent variability observed in language development (even among monolingual speakers); different children will recruit different resources to process language under different demands. Nevertheless, our findings add to this body of research by demonstrating that the relationship between receptive language and verbal memory is also not straightforward in bilingual children in that similar measures in two languages may not be measuring the same underlying skill. We also know from studies such as that of Ardilla (2003) that similar verbal-short term memory tasks lead to different span scores across different languages. The auditory controlled attention task is in essence a task requiring the comprehension of language under increased processing demands (the presence of background meaningful speech) and it is to be expected that children who have a lower level of proficiency in the language of the test will do more poorly because of their lower level of proficiency in that language. Therefore, the children in this study with lower scores on verbal memory most likely have less proficiency in that language and thus perform more poorly on the auditory controlled task.

Our findings are in contrast to those of Kohnert et al. (2006) who found that the performance of their bilingual group on English NWR and English CLPT fell between the typically developing monolingual English speakers and those with language impairment. However they tested children's verbal working memories only in English in the Spanish-English bilinguals who were reported to be highly proficient in English. In our sample, the TD-B group, who was also highly proficient in both languages, did better than the typically developing group with unbalanced exposure on only the CLPT in French, but did as well as the TD-b group on all other verbal memory measures in English and in French. The same pattern of results was found for the auditory controlled attention task when we look at the raw scores. The TD-B and TD-b groups showed similar performance in English with the TD-B doing better in French. However, the children with SLI had lower scores on 3 different verbal memory measures. Therefore, based on raw scores, our balanced bilingual children actually did better than the other two groups on both the auditory controlled attention task and the verbal memory measures, followed by the TD-b group, and finally the SLI-b group, even though these differences were not significant. The main difference between our study and that of Kohnert et al. (2006) is that we were comparing bilinguals with varying proficiencies to those with balanced exposure instead of comparing the latter to monolinguals.

In summary, our results are consistent with other studies with monolingual children with SLI showing normal visuospatial memory and visual processing abilities (Archibald & Gathercole, 2006; Nation, Adams, Bowyer-Crane, & Snowling, 1999: Spaulding et al., 2008). Archibald & Gathercole (2006) found that their 9 year old children with SLI performed similarly to their same age peers on a series of visuospatial memory tasks. Others, such as Hoffman and Gillam (2004), found that in 9-year olds with SLI, spatial recall was lower than in their age-matched peers; however, their task was more complex than ours or the ones used in Archibald & Gathercole (2006). Task complexity is an important factor to consider, as Engle and colleagues have pointed out (e.g. Engle et al., 1999); many so-called memory tasks are more likely on a continuum of short-term to working memory depending on the age and abilities of the participants. Spaulding et al.'s (2008) results indicated that monolingual English-speaking preschool children with SLI had poorer performance under high attentional load auditory sustained selective attention tasks with similar performance on visual sustained selective attention tasks. Furthermore, both groups showed similar reaction times across both visual and verbal sustained selective attention tasks. Our findings on visual controlled attention and visuospatial memory are consistent with some of this previous research in monolingual children with SLI (Schul et al., 2004; Spaulding et al., 2008).

The findings from the auditory controlled attention task, however, seem to indicate that there is a cumulative effect of SLI and unbalanced bilingualism as evidenced by the poorer performance of the SLI-b group compared to the TD-B group, but not the unbalanced bilingual children. The results of the auditory controlled attention task are also consistent with one study that used a similar task in monolingual children with and without SLI. For example, Stevens et al. (2006) had 6-year old children matched on age, SES, and IQ with and without SLI hear different stories spoken by different (male or female) speakers presented to different ears simultaneously. The children were instructed to attend to a particular story (and ignore the other); the children with SLI, unlike the typically developing children, showed a smaller ERP response to the attended versus the unattended story.

The current study, although very preliminary, is the first of its kind to investigate visual controlled attention, auditory controlled attention, visuospatial memory, and verbal memory in relation to language impairment and level of bilingualism in bilingual children. First, it demonstrates that visuospatial memory and visually controlled attention are unaffected by unbalanced exposure to two languages or the presence of a language impairment. Since balanced bilingual children don't do any better than unbalanced ones, balanced bilingualism is not associated with the better performance that is found in other groups as has been claimed (Bialystok, 1999). It also demonstrates that in the case of bilingual children with SLI who have unbalanced exposure, there is a cumulative effect of level of bilingualism and language impairment. Furthermore, verbal memory seems to mediate the ability to resist interference in the auditory modality for children with unbalanced exposure and SLI. An additional possible implication is that a task similar to the auditory controlled attention one used in this study may be useful as a research and clinical tool in distinguishing balanced bilingual children with normal language skills from those with language disorders. The advantage of such a task would be that it is a single computerized task. Traditional language testing in bilingual children has to be done by a native speaker of each language. Nevertheless, according to our current results, all three groups were separated by traditional language tests but not by the auditory controlled task. We know from our previous two investigations that monolingual and balanced bilingual children perform similarly on the auditory controlled attention task when compared to each other in the appropriate language. However, in the case of unbalanced bilinguals with language impairment, they perform more poorly than balanced bilinguals. What is needed in future studies is a larger number of children per group to determine whether differences exist between the TD-b and SLI-b groups, as well as an investigation of auditory controlled attention in *balanced* bilingual children with SLI.

Our results showed that unbalanced exposure does not have a detrimental effect in either the visual or auditory modality, however unbalanced exposure in the presence of SLI does. Interestingly though, despite significant differences in Leiter scores from the control group, the SLI-b children still performed similarly to the TD-b group on the auditory controlled attention task as well as similarly to both the TD-b and TD-B groups on the Simon task. Ultimately, including a group of balanced bilingual children with SLI may allow us to determine with more certainty whether or not equalizing language exposure diminishes or extinguishes the cumulative effect. This is a possibility worth considering since in this study, the children with SLI did as well on the auditory controlled attention task as those with unbalanced exposure. If the balanced bilingual children with SLI perform as well as those without SLI, then we can be more certain that unequal exposure affects performance on language comprehension measures under increased processing load. This will allow us to be more certain in our recommendations to parents of bilingual children with SLI in that perhaps consistent equal exposure to two languages does not exacerbate language problems. Alternatively, it may be that this group difference is temporary. As shown in comparing the findings reported by Elin Thordardottir (2006) and (2008), young simultaneous bilingual preschool children lag behind their monolingual peers in language scores, whereas 5-year old bilingual children score similarly to monolingual peers. Therefore, it may be that unbalanced bilingualism does not exacerbate SLI but that it slows down development in each language such that similar performance to monolingual children or balanced bilingual children will take longer. Finally, future studies with larger numbers of children using similar auditory controlled attention tasks are needed to determine whether such tasks have any greater efficacy than the current more common linguistic processing measures in discriminating bilingual children with SLI from their typically developing same-age peers.

Tables

Table 1.

Participant characteristics showing means and (SDs) for typically developing bilingual children with unbalanced exposure (TD-b), bilingual children with SLI (SLI-b), and typically developing bilingual children with balanced exposure (TD-B)

	TD-b	**SLI-b**	**TD-B**
Age in months	59.13 (2.5)	64.25 (9.2)	59.0 (4.9)
Gender	6 M, 2 F	7 M, 1 F	3 M, 5 F
Leiter-R	108.7 (7.7)	88.1 (6.1)	111.6 (14.2)
Maternal ed.	17.5 (2.3)	16.6 (2.6)	17.3 (1.7)

Note:

Leiter-R scores are standard scores for Brief IQ

Maternal education is reported in years of school completed including elementary school and all subsequent years

Table 2.
Means and standard deviations for all language measures for typically developing bilingual children with unbalanced exposure (TD-b), bilingual children with SLI (SLI-b), and typically developing bilingual children with balanced exposure (TD-B). Where the number of participants was less than 8 group per group, this has been noted by n in parentheses.

	TD-b	**SLI-b**	**TD-B**
EVIP	86(25.8)	63.1 (22.5)	113.1 (9.4)
PPVT	100.9 (17.4)	77.5 (8.6)	100.7 (16.3)
CELF-P2	89.4 (19.9)	65.9 (10.6)	97.8 (19.5) (n=6)
MLUm French	5.0 (1.9) (n=6)	3.9 (0.9) (n=7)	6.1 (1.3)
MLUm English	3.9 (0.9) (n=7)	3.1 (0.5)	4.2 (1.0)
Sentence Imitation French	0.6 (0.3) (n=7)	0.4 (0.2)	0.9 (0.1)
Sentence Imitation English	0.8 (0.2)	0.4 (0.2)	0.8 (0.2)

Note:
EVIP, CELF-P2 scores are standard scores
NEEL 7 is a raw score out of 6

Table 3.
Means and standard deviations for verbal and nonverbal memory measures for typically developing bilingual children with unbalanced exposure (TD-b), bilingual children with SLI (SLI-b), and typically developing bilingual children with balanced exposure (TD-B). Where the number of participants was less than 8 group per group, this has been noted by n in parentheses.

	TD-b	**SLI-b**	**TD-B**
Forward digit span - French	5.7 (1.5)	4.1 (1.1)	6.9 (2.4)
Forward digit span - English	5.6 (1.7)	3.5 (1.4)	6.5 (0.9)
Nonword repetition - French	0.82 (0.08)	0.70 (0.14)	0.93 (0.04) (n=7)
Nonword repetition – English	0.86 (0.11)	0.65 (0.27)	0.85 (0.13) (n=7)
CLPT – French	0.21 (0.20)	0.11 (0.11)	0.44 (0.07) (n=7)
CLPT – English	0.43 (0.14)	0.20 (0.15)	0.31 (0.20)
Visuospatial memory	10.6 (5.8)	12.8 (4.0) (n=7)	14.1 (3.5)

Note:
Verbal memory measures reported as percentages. Nonverbal memory measures is a raw score out of 20.

Table 4.
Summary of Post-hoc comparisons on all memory measures for typically developing bilingual children with unbalanced exposure (TD-b), bilingual children with SLI (SLI-b), and typically developing bilingual children with balanced exposure (TD-B).

Forward digit span - French	**TD-B > SLI-b = TD-b**
Forward digit span - English	TD-B = TD-b > SLI-b
Nonword repetition - French	**TD-B > TD-b > SLI-b**
Nonword repetition – English	TD-B = TD-b > SLI-b
CLPT – French	**TD-B > TD-b = SLI-b**
CLPT – English	TD-B = TD-b > SLI-b
Visuospatial memory	TD-B = TD-b = SLI-b

Table 5.
Auditory controlled attention means and standard deviations by each group in each of the inter and intra-language conditions tested. Where the number of participants was less than 8 group per group, this has been noted by n in parentheses. The maximum score possible for each condition is 18.

Condition:	**FE**	**FF**	**EE**	**EF**
Group:				
TD-b	9.4 (3.3) (n=7)	7.4 (4.2) (n=7)	9.4 (1.8)	8.0 (2.3)
SLI-b	7.6 (2.9)	6.4 (3.2)	7.6 (3.1)	6.9 (2.5)
TD-B	12.7 (2.2) (n=7)	11.8 (3.9)(n=7)	9.7 (2.5)	7.9 (2.4)

Note: FF: French intralingual condition (French targets, French story)
FE: French interlingual condition (French targets, English story)
EE: English intralingual condition (English targets, English story)
EF: English interlingual condition (English targets, French story)

General Discussion

The three manuscripts that make up this thesis addressed the relationship between working memory and controlled attention in the visual and auditory modalities in monolingual and bilingual children with and without SLI. The general objectives of the first study were to determine whether or not a bilingual advantage in visual controlled attention exists when monolingual and bilingual children are equated on measures of visual and verbal working memory. Secondly, we wanted to explore the relationship between visual working memory and visual controlled attention in the three groups of children who participated in the study. The main aim of the second study was to determine how bilingual children compared to their monolingual peers on an auditory-verbal controlled attention task that simulates the bilingual experience and has been put forward as the explanation for the observed bilingual advantage in the visual domain. A second aim was to look at the relationship between auditory-verbal working memory and auditory controlled attention. The third study extended the purposes of study one and two to bilingual children with SLI matched on level of bilingualism to a control group of bilinguals without language impairment. A second aim was to conduct a preliminary investigation of the effect of balanced versus unbalanced language exposure on visual and auditory controlled attention.

The first study clearly showed that when bilingual and monolingual children are matched on measures of visual and verbal working memory, there are no differences in their capacities in controlled attention as measured by the Simon task. Unlike the children in some of the previous research on the bilingual advantage in controlled attention, the children in this study formed a very homogeneous group of simultaneous bilinguals exposed to the same two languages from birth. Furthermore, they were well matched on not only age, nonverbal IQ, verbal short-term memory, and SES, but also on verbal and visual working memory. The bilingual children were also very similar to each of the monolingual groups on all measures of language knowledge in both of their languages. Therefore, the only pertinent difference among the three groups was whether they spoke one or two languages, thereby allowing us to successfully isolate the variable of interest--bilingualism. Conversely, when the participants were divided into two groups according to high and low visual working memory those with higher spans showed superior performance both in speed and accuracy on the Simon task. Furthermore, we found a strong positive relationship between reaction times and accuracy scores on the Simon task and visual working memory, but no relation with verbal working memory or verbal short-term memory. Taken together, these findings provide strong evidence for the idea that performance on the Simon task is, at least in part, mediated by the capacity to store and manipulate visuospatial information. In the second study, we simulated the real-world experience of a bilingual individual by creating an auditory controlled attention task that required the children to attend and process sentences in one language while ignoring meaningful speech occurring in parallel. The practice in attending to one language while ignoring the other has been given as the explanation for the bilingual's domain-general superior performance in controlled attention. The bilingual and monolingual children in our study performed similarly on this task. Furthermore, when groups were split according to high and low verbal working memory, those with higher spans were more accurate on the auditory controlled attention task. The same was not true for verbal short-term memory. The third study extended our aims to bilingual children with and without SLI as well as a smaller subset of the balanced bilingual children who participated in studies two and three. There were no group differences in visual controlled attention or visuospatial working memory and when we split the two unbalanced groups according to high and low span, we failed to find a group difference. However, the results for verbal working memory were confirmed in this third study and there was also a strong relationship between verbal short-term memory (as measured by nonword repetition) and the auditory controlled attention task in the two unbalanced bilingual groups.

Our findings support and can be explained by appealing to the model of working memory developed by Engle et al. (1999). The results from the first two studies in the visual domain and from all three studies in the verbal domain demonstrated that those children with high working memory spans outperformed those with relatively lower spans on both the auditory and visual controlled attention measures. Engle et al. (1999) posit a highly interrelated relationship between working memory and controlled attention in that individual differences in working memory capacity can actually determine the ability to control attention. Rosen and Engle (1998), for example, demonstrated that the ability to suppress intrusive thoughts and behaviors, which requires controlled attention, is highly dependent on an individual's working memory capacity. Engle (2002) also showed that controlled attention varied as a function of working memory capacity. For example, he found that even individuals with equivalent arithmetic skill still demonstrated differences in the number of words recalled in the operation span task, which actually correlated with performance in reading comprehension. Therefore, as Engle also suggested, greater working memory capacity may mean greater ability to use attention to avoid distraction and dealing with the effects of interference (that is, controlled attention) is one of the primary *functions* of working memory.

Eastwood (2002) explored working memory capacity in children between the ages of 9 and 13. In addition to other aims, she addressed whether working memory is separate from short-term memory and the relative contributions of controlled attention and short-term memory in accounting for individual differences in working memory capacity. She found that working memory was *distinct* from but strongly correlated with controlled attention. Her results are in concert with ours and can be explained by the Engle et al. (1999) model of working memory as controlled attention. This model was chosen because in contrast to the more prevalent models of working memory (see Baddeley, 1974, 1986, 2000 or Just & Carpenter, 1980), it incorporates domain-free, as well as domain-specific properties and considers various knowledge states as they relate to *individual* differences. Furthermore, the Engle et al. (1999) model, unlike the others, clearly specifies and adequately defines the role of controlled attention which is currently at the centre of the cognitive advantage literature in bilingualism and is the focus of the three studies in this thesis. This model details a continuous relationship between working memory, short-term memory, and controlled attention. As described earlier, in this model, the underlying working memory construct is viewed as continuous, ranging from individuals who have *more* attentional resources (or can regulate resources more effectively) to those who have *fewer* resources (or who regulate less well) (Barrett, Tugade, & Engle, 2004). The specific features of the model are: (1) domain-free, limited capacity controlled attention, (2) domain-specific codes and maintenances (phonological loop and visuospatial sketchpad are but two), (3) individual differences in capacity for controlled processing are general, (4) limited capacity, controlled processing is needed for maintaining temporary goals in the face of distraction and interference. According to Engle's model, the situations in which individual differences in working memory capacity and controlled attention could *interact* are when: (1) task goals are lost unless actively maintained in working memory, (2) actions competing for responding or response preparation must be scheduled, (3) conflict among actions must be resolved to prevent error, (4) maintaining some task information in the face of distraction and interference, (5) suppressing or inhibiting information irrelevant to the task, (6) error monitoring and correction are controlled and effortful, (7) controlled search of memory is necessary or useful. Engle et al. (1999) maintain that there are no 'pure' short term memory or working memory tasks; instead they are graded in the extent to which they are "good" short-term memory or working memory tasks depending on the overlap in task content or materials, in procedures used to perform the task, and on the extent to which tasks require controlled attention.

Both controlled attention tasks in our studies involved the situations described above where individual differences in working memory and controlled attention can interact. In the case of the Simon task, children have to keep in mind the goal of the task (press the red button when you see the red square and the blue button when you see the blue square) (situation 1) and they have to overcome the tendency to press the wrong coloured button when the corresponding square is on the opposite side of the screen (situations 3, 4, and 5). Finally, the task qualifies also for situation 6 because the stimuli appear and disappear at a rapid rate, therefore error monitoring and correction are effortful. In the case of the auditory controlled attention task, situations 4 to 7 hold. Children have to focus their attention on the sentences that correspond to the pictures on the screen, while ignoring the incoming meaningful background story; they have to temporarily store the sentence, process it, then make a decision as to the correct answer. Therefore, in addition to being a task that requires effortful control, a memory search is also useful in order to attach meaning to the sentences heard. When we compare groups of children as in study one and two who are matched on visuospatial working memory, verbal working memory, and verbal short-term memory, no differences emerge on these two tasks. However, once we separate children according to performance on the working memory tasks, that is, once we consider individual differences in working memory capacity, then we observe that children who have higher spans in the visual domain score better on the Simon task and those with higher spans in the auditory-verbal domain perform better on the auditory controlled attention task. Taken together, our findings demonstrate that working memory capacity determines the ability to control attention.

The results of study three in the visual domain are more difficult to explain however, because there is no discernable relationship between performance on the Simon task and visuospatial working memory in the two groups of children with unbalanced exposure. No group differences emerge when children are split into high and low visuospatial working memory groups. One limitation of this study was that group sizes were relatively small, so statistical power may not have been sufficiently high to provide sensitivity to small but consistent differences. The other possibility is that visuospatial working memory as measured by the Pattern recall task does not mediate performance on the Simon task in the children with unbalanced bilingual exposure. This lack of a group difference may have emerged because the two groups of bilingual children with unbalanced exposure are simply too similar; that is, there is not enough variance in either the visuospatial memory scores or the Simon task scores. Another possibility is that the larger variance (as compared to the balanced bilingual group) in visuospatial working memory scores in the two groups with unbalanced exposure masks the relationship between visuospatial working memory and the Simon task and further underlines the importance of future studies with larger groups of children.

Nevertheless, the third study does make important contributions to our understanding of verbal and nonverbal processing in bilingual children with language disorder and is the first to do so in comparison to children matched on level of bilingualism, instead of using the monolingual comparison as the gold standard. The bilingual children with SLI are significantly delayed in their verbal abilities as measured by both the language knowledge testing as well as the linguistic processing measures (verbal working memory and verbal short-term memory). What is interesting, however, is that they still perform similarly to both other groups on both of the visual processing measures (Pattern recall and the Simon task). These findings are in line with those of

Archibald and Gathercole (2006) for monolingual children with SLI and suggest that there is not a significant deficit in visual memory and visual processing in bilingual children with SLI. Furthermore, the differential performance of the SLI children in the visual and verbal domains, along with the associations found in the first two studies between verbal working memory and auditory controlled attention on the one hand and visuospatial working memory and visual controlled attention on the other hand, seem to support the notion that the visuospatial and verbal domains of memory can be fractionated (e.g. Baddeley, 1974; 1986; 2000; Shah & Miyake, 1996). The children in our three studies had wide ranging nonverbal and verbal abilities as measured by several different tasks, therefore it cannot be argued that the fractionation is observed due to a restricted range of cognitive ability. Another important finding that emerges from the third study is that, in the verbal domain, the combination of unbalanced exposure and SLI has a cumulative and negative effect on the ability to process sentences under effortful conditions. Furthermore, for the two unbalanced bilingual groups, there is also a strong relationship between verbal short-term memory (as measured by nonword repetition) and auditory controlled attention--an association which was not evident for the balanced bilingual and monolingual groups. This finding further supports Engle et al.'s (1999) notion that short-term memory and working memory are on a continuum and may not necessarily be distinct at all stages of development, for all children with varying abilities. It is possible that for the unbalanced bilingual groups, the linguistic processing measures in both languages are more effortful than for the balanced bilingual and monolingual groups. As a result, we observe associations between the auditory controlled attention task and both verbal memory measures.

The three manuscripts making up this thesis demonstrate that there is a complex and variable relationship between working memory capacity and controlled attention. Although each of these constructs has a distinct role, they interact and are integral to the control of behavior (Luna, Garver, Urban, Lazar, & Sweeney, 2004). This evidence demonstrates that the 'cognitive advantage' in controlled attention observed in previous research with balanced bilingual children may actually have been due to linguistic processing and/or linguistic knowledge differences between the bilingual and monolingual groups. Potential differences in working memory capacity present a confounding factor in concluding that bilingualism leads to an advantage in controlled attention. Furthermore, the very skill that has been put forward as leading to the advantage in bilingualism was tested in study two and bilingual children did not perform any better than the monolingual groups. Therefore, the construct to which the advantage in controlled attention has been attributed remains debatable. Finally, these three studies have also clearly shown that irrespective of level of bilingualism, or the presence of language impairment, performance on visual controlled attention is equivalent – this is in direct contrast to the argument in the cognitive advantage literature that it is balanced bilinguals that benefit from superior performance. Future studies with larger groups of bilingual children with and without language impairment using a greater number of tasks tapping into visual and auditory controlled attention are needed. It is also important that the tasks are varied in their processing demands, as well, in order to allow us to discern not only associations between different types of memory measures and controlled attention, but to also to be able to differentiate bilingual children with unbalanced exposure with SLI from those with typical development.

References

Adams, A.M., Bourke, L., & Willis, C. (1999). Working Memory and Spoken Language Comprehension in Young Children. *International Journal of Psychology*, *34,* 364-373.

Alloway, T.P., Gathercole, S.E., & Pickering, S.J. (2006). Verbal and visuospatial short-term and working memory in children: Are they separable? *Child Development*, *77,* 1698-1716.

Archibald, L.M.D. & Gathercole, S.E. (2006). Visuospatial immediate memory in Specific Language Impairment. *Journal of Speech, Language, and Hearing Research*, *49,* 265-277.

Ardila, A. (2003). Language representation and working memory with bilinguals. *Journal of Communication Disorders*, *36*, 233–240.

Ardila, A., Rosselli, M., Ostrosky-Solis, F., Marcos, J., Granda, G., & Soto, M. (2000). Syntactic comprehension verbal memory and calculation abilities in Spanish-English bilinguals. Applied. *Neuropsychology*, *7*, 3–16.

Baddeley, A.D. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences*, *4,* 417–423.

Baddeley, A.D. (1986). *Working Memory*. Oxford: Clarendon Press.

Baddeley, A.D. & Logie, R.H. (1999). Working Memory: The multiple-component model. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 28-61).

Bahrrick, H.P., Hall, L.K., Goggin, J.P., Bahrick, L.E., & Berger, S.A. (1994). Fifty years of language maintenance and language dominance in bilingual Hispanic immigrants. *Journal of Experimental Psychology: General, 123,* 264-283.

Barrett, L. F., Tugade, M. M., & Engle, R. W. (2004). Individual Differences in Working Memory Capacity and Dual-Process Theories of the Mind. *Psychological bulletin, 130,* 553-573.

Ben-Zeev, S. (1977). The influence of bilingualism on cognitive strategy and cognitive development. *Child Development*, *48*, 1009-1018.

Bialystok, E. (2006). Effect of bilingualism and computer video game experience on the Simon task. *Canadian Journal of Experimental Psychology, 60,* 68-79.

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development, 70,* 636-644.

Bialystok, E. (1998). Levels of bilingualism and levels of linguistic awareness. *Developmental Psychology, 24,* 560-567.

Bialsytok, E. (1986). Children's Concept of Word. *Journal of Psycholinguistic Research, 15*.

Bialystok, E., Craik, F.I.M., Klein, R., and Viswanathan, M. (2004). Bilingualism, aging, and cognitive control : Evidence from the Simon task. *Psychology and Aging*, *19,* 290-303.

Bialystok, E. Craik, F.I.M., Luk, G. (2008). Lexical access in bilinguals : Effects of vocabulary size and executive control. *Journal of Neurolinguistics, 21*, 522-538.

Bialystok, E. & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental science, 7,* 325-339.

Bialystok, E. and Senman, L. (2004). Executive processes in appearance-reality tasks : The role of inhibition of attention and symbolic representation. *Child Development*, *75,* 562-579.

Bialystok, E. and Shapero, D. (2005). Ambiguous benefits : The effect of bilingualism on reversing ambiguous figures. *Developmental Science, 8*, 595-604.

Bialystok, E. Martin, M.M., and Viswanathan, M. (2005). Bilingualism across the lifespan : The rise and fall of inhibitory control. *International Journal of Bilingualism, 9,* 103-119.

Bialystok, E. and Shapero, D. (2005). Ambiguous benefits : The effect of bilingualism on reversing ambiguous figures. *Developmental Science, 8,* 595-604.

Blake, J., Austin, W., Cannon, M., Lisus, A., & Vaughan, A. (1994). The relationship between memory span and measures of imitative and spontaneous language complexity in preschool children. *International Journal of Behavioural Development, 17,* 91-107.

Boulianne, L. & Labelle, M. (2006). Unpublished working version of a French adaptation of the digit span subtest of the CELF-4. Montreal.

Bronckart, J.P. & Sinclair, H. (1973). Time, tense, and aspect. *Cognition, 2*, 107-130.

Burns, T. C, Yoshida, K., Hill, K., & Werker, J. F. (2007). The development of phonetic representation in bilingual and monolingual infants. *Applied Psycholinguistics, 28*, 455-474.

Cantor, J., Engle, R. W., & Hamilton, G. (1991). Short-term memory, working memory, and verbal abilities: How do they relate? *Intelligence, 15,* 229-246.

Carrow-Woolfolk, E. (1999). Test for Auditory Comprehension of Language, Third edition. Austin, TX: Pro-Ed.

Cheuk, D.K.L., Wong, V., & Leung, G.M. (2005). Multilingual home environment and Specific Language Impairment: A case control study in Chinese children. *Paediatric and Perinatal Epidemiology, 19,* 303–314.

Chevrie-Muller, C. and C. Plaza (2001). Nouvelles Epreuves pour l'Examen du Langage. Paris, Editions du Centre de Psychologie Appliquée.

Chincotta, D. & Underwood, (1997). Estimates, language of schooling and bilingual digit span. *European Journal of Cognitive Psychology, 9,* Sep-348.

Conway, A.R.A., Cowan, N. & Bunting, M.F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review, 8,* 331-335.

Courcy (2000). Conscience phonologique et apprentissage de la lecture. Unpublished doctoral dissertation. Montréal: Université de Montréal.

Cummins, J. (2004). Language and literacy in bilingual children. *Journal of child language, 31,* 424-429.

Cummins, J. & Mulcahy, R. (1978). Orientation to language in Ukrainian-English bilingual children. *Child Development, 49,* 1239-1242.

Daneman, M. and Carpenter, P.A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behaviour, 19,* 450--466.

Daneman, M. & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic bulletin & review, 3,* 422-433.

Dawson, G., Ashman, S. B., & Carver, L. J. (2000). The role of early experience in shaping behavioral and brain development and its implications for social policy. *Development and Psychopathology, 12,* 695-712.

Dunn, L.M., & Dunn, L.M. (1997). Peabody Picture Vocabulary Test, Third Edition. Circle Pines, MN: American Guidance Service.

Dunn, L., Thériault-Whalen, C. & Dunn, L. (1993). *Échelle de vocabulaire en images Peabody: Adaptation française du Peabody Picture Vocabulary Test-Revised.* Toronto, IN: PsyCan.

Eastwood, E. A. (2002). *Memory or attention? Understanding working memory in children.* Unpublished doctoral dissertation, University of Waterloo, Waterloo, Ontario, Canada.

Elin Thordardottir (2008). Relationship between amount of language exposure and language scores in older preschoolers acquiring French and English simultaneously. Presented at IASCL (International Association for the Study of Child Language), Edinburgh, August..

Elin Thordardottir (2008b). Language specific effects of task demands on the manifestation of specific language impairment: A comparison of English and Icelandic. *JSLHR*, *51*, 922-937.

Elin Thordardottir (2006). Unpublished French adaptation of the Competing Language Processing Task. Montreal: McGill University.

Elin Thordardottir (2005). Early lexical and syntactic development in Quebec French and English: implications for cross-linguistic and bilingual assessment. *International Journal of Communication Disorders*, *40*, 243-278.

Elin Thordardottir, Kehayia, E., N. Lessard, Sutton, S. & Trudeau, N. (submitted). Performance on measures of language knowledge and language processing in French-speaking 5-year olds. JOURNAL NAME.

Elin Thordardottir, Kehayia, E., N. Lessard, Sutton, S. & Trudeau, N. (2007). Sensitivity and specificity of diagnostic measures for the identification of language impairment in French. Talk presented at the 27th congress of the IALP (International Association of Logopedics and Phoniatrics), Copenhagen, August.

Elin Thordardottir, Rothenberg, A., Rivard, M.E., and Naves R. (2006). *Journal of Multicultural Communication Disorders, 4,* 1-21.

Elliot, L.L., Connors, S., Kille, E., Levin, S., Ball, K., & Katz, D. (1979). Children's understanding of monosyllabic nouns in quiet and in noise. *Journal of the Acoustical Society of America, 66,* 12–21.

Ellis, N. C. & Sinclair, S. G. (1996). Working memory in the acquisition of vocabulary and syntax: Putting language in good order. *The Quarterly Journal of Experimental Psychology, 49A,* 234-250.

Ellis Weismer S. (1996) *Topics in Language Disorders*. 17, 33-44.

Ellis Weismer S., Evans J., and Hesketh L.J. (1999) *Journal of Speech, Language, and Hearing Research*. 42, 1249-1260.

Engle (2002). Working memory capacity as executive attention. *Current directions in psychological science, 11*, 19-23.

Engle, R.W., Kane, M. J., & Tuholski, S. W. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence, and functions of the prefrontal cortex. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 102-134).

Engel, P.M.J., Santos, F.H., & Gathercole, S.E. (2008). Are working memory measures free of socioeconomic influence? *Journal of Speech, Language, Hearing Research, 51*, 1580-1587.

Epsy, A. K., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The Contribution of Executive Functions to Emergent Mathematic Skills in Preschool Children. *Developmental Neuropsychology, 26,* 465-486.

Epsy, A. K., Molfese, V. J., & DiLalla, L. F. (2001). Effects of environmental measures on intelligence in young children: Growth curve modeling of longitudinal data. *Merrill-Palmer quarterly, 47,* 42-73.

Fallon, M., Trehub, S.E., & Schneider B.A. (2000). Children's perception of speech in multitalker babble. *Journal of the Acoustical Society of America, 108,* 3023–3029.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science*, 18, 850-855.

Gathercole, S.E. and Baddeley, A.E. (1989). Evaluation of the role of phonological STM in the development of vocabulary in children : A longitudinal study. *Journal of Memory and Language, 28,* 200-213.

Gathercole, S.E, and Baddeley, A.D. (1990a) Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory & Language.* 29, 336-360.

Gathercole, S. E. & Pickering, S. J. (2000). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology, 70,* 177-194.

Gathercole, S.E., Service, E., Hitch, G.J., Adams, A.M., & Martin, A.J. (1999). Phonological short-term memory and vocabulary development: Further evidence on the nature of the relationship. *Applied Cognitive Psychology, 13*, 65-77.

Gathercole, S.E., Willis, C.S., Baddeley, A.E., and Emslie, H. (1994). The children's test of nonword repetition : A test phonological working memory. *Memory, 2,* 103-127.

Gaulin, C.A. & Campbell, T.F. (1994). Procedure for assessing verbal working memory in normal school-age children: Some preliminary data. *Perceptual Motor Skills, 79,* 59-64.

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3-7 years old on a Stroop-like day night test. *Cognition, 53*, 129-153.

Girbau, D. & Schwartz, R.G. (2008). Phonological working memory in Spanish-English bilingual children with and without Specific Language Impairment. *Journal of Communication Disorders, 41*, 124-145.

Goetz, P.J. (2003). The effects of bilingualism on theory of mind development. *Bilingualism : Language and cognition, 6,* 1-15.

Green, D.W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism : Language and Cognition, 1,* 67-81.

Green, C.S. & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*, 534-537.

Grosjean, F. (1998). Studying bilinguals: Methodological and conceptual issues. *Bilingualism language and cognition, 1,* 131-149.

Groupe coopératif en orthophonie- Région Laval, Laurentides, Lanaudière (1995).Épreuve de compréhension de Carrow-Woolfolk, adaptation française du Test of Auditory Comprehension of Language-R. Unpublished guidelines.

Gutiérrez-Clellen, V.F., Calderón, J., & Ellis Weismer, S. (2004). Verbal working memory in bilingual children. *Journal of speech, language, and hearing research, 47*, 863-876.

Hick, R.F., Botting, N., & Conti-Ramsden, G. (2005). Short-term memory and vocabulary development in children with Down Syndrome and children with Specific Language Impairment. *Developmental Medicine & Child Neurology, 47*, 532-538.

Ho, Y., Cheung, M., & Chan, A.S. (2003). Music training improves verbal but not visual memory: Cross-sectional and longitudinal explorations in children. *Neuropsychology, 17 (3),* 439-450.

Hoff, E. (2003). Causes and consequences of SES-related differences in parent-to-child speech In Socioeconomic status, parenting, and child development (pp. 147-160).

Hoffman, L.M. & Gillman, R.B. (2004). Verbal and spatial information processing constraints in children with Specific Language Impairment. *Journal of Speech, Language, and Hearing Research, 47*, 114-125.

Hughes, C. (1998). Executive function in preschoolers: Links with theory of mind and verbal ability. *British Journal of Developmental Psychology, 16,* 233-253.

Ianco-Worrall, A. D. (1972). Bilingualism and cognitive development. *Child Development, 43,* 1390-1400.

Jarrold, C., Baddeley, A.D., and Hewes, A.K. (1999). Genetically dissociated components of working memory : Evidence from Down's and Williams syndrome. *Neuropsychologia, 37,* 637-651.

Johnston, J.R. (1988) Specific language disorders in the child, in N. Lass, J. Northern, L. McReynolds, and D.E. Yoder (Eds.) *Handbook of Speech-Language Pathology and Audiology,* 685-715. Philadelphia: B.C. Decker.

Johnston, J.R. & Ellis Weismer, S. (1983). Mental rotation abilities in language-disordered children. *Journal of Speech and Hearing Research, 26*, 397-403.

Just, M.A. & Carpenter, P.A. (1980). A theory of reading: from eye fixations to comprehension. *Psychological Review, 87*, 329-354.

Kay-Raining Bird, E., Cleave, P., Trudeau N., Elin Thordardottir, & Sutton, A. (2005). The language abilities of children with Down Syndrome. *American Journal of Speech-Language Pathology, 14*, 187-199.

Kohnert, K., Windsor, J., & Ebert, K.D. (2009). Primary or “specific” language impairment and children learning a second language. *Brain and Language, 109,* 101-111.

Kohnert, K., Windsor, J., & Yim, D. (2006). Do language-based processing tasks separate children with language impairment from typical bilinguals. *Learning Disabilities Research and Practice, 21*, 19-29.

Kovacs, A.M. & Mehler, J. (2009). Cognitive gains in 7-month old bilingual infants. *Proceedings of the National Academy of Sciences, 106*, 6556-6560.

Leonard, L.B. (1998) Children with specific language impairment.

Lew, H. & Jerger, J. (1991). Effect of linguistic interference on sentence identification. *Ear and Hearing, 12*, 365-367.

Liss, M., Fein, D., Allen, D., Dunn, M., Feinstein, C., Morris, R., Waterhouse, L., & Rapin, I. (2001). Executive functioning in high-functioning children with Autism. *Journal of Child Psychology and Psychiatry, 42*, 261-270.

Lum. J.A.G. & Bavin, E.L. (2007). Analysis and control in children with SLI. *Journal of Speech, Language, and Hearing Research, 50*, 1618-1630.

Luna, B., Garver, K.E., Urban, T.A., Lazar, N.A., Sweeney, J.A. (2004). Maturation of cognitive processes from late childhood to adulthood. *Child Development, 75*, 1357-1372.

Maguire, E. A., Gadian, D. G., Johnsrude, I. S., Good, C. D., Ashburner, J., Frackowiak, R. S. & Frith, C. D. (2000). Navigation-related structural changes in the hippocampi of taxi drivers. *Proceedings of the National Academy of America*, 97, 4398–4403.

Martin-Rhee, M.M. and Bialystok, E. (2008). The development of two types of inhibitroy control in monolingual and bilingual children. *Bilingualism : Language and Cognition, 11,* 81-93.

Marton K., and Schwartz R.G. (2003) *Journal of Speech, Language, and Hearing Research. 46,* 1138-1153.

Mayo, L.H., Florentin, M. & Buus, S. (1997). Age of second language acquisition and perception of speech in noise. *Journal of Speech, Language & Hearing Research, 40*, 686-694.

Mezzacappa, E. (2004). Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Development*, *75*, 1373–1386.

Miyake, A., Friedman, N.P., Rettinger, D.A., Shah, P., & Hegarty, M. (2001). How are visuospatial working memory, executive functioning, and spatial abilities related? A latent-variable analysis. *Journal of Experimental Psychology: General, 130,* 121-640.

Miyake, A. & Shah, P. (1999). Toward unified theories of working memory: Emerging general consensus, unresolved theoretical issues, and future research directions. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 442-481).

Montgomery, J.W. (2003). Working memory and comprehension in children with specific language impairment: what we know so far. *Journal of Communication Disorders, 36,* 221-231.

Montgomery, J.W. (2002). Information processing and language comprehension in children with Specific Language Impairment. *Topics in Language Disorders, 22*, 62-84.

Montgomery, J.W. (2000a). Verbal working memory and sentence comprehension in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 43(2),* 293-308.

Montgomery, J.W. (2000b) Relation of working memory to off-line and real-time sentence processing in children with specific language impairment. *Applied Psycholinguistics. 21,* 117-148. Montgomery, J.W. (1995a) Sentence comprehension in children with specific language impairment: The role of phonological working memory. *Journal of Speech & Hearing Research. 38,* 187-199. Montgomery, J.W. (1995b) Examination of phonological working memory in specifically language-impaired children. *Applied Psycholinguistics. 16*, 355-378.

Morton, J.B. and Harper, S.N. (2007). What did Simon say? Revisiting the bilingual advantage. *Developmental Science, 10,* 719-726.

Namazi, M. & Elin Thordardottir (in revision). A working memory, not a bilingual advantage, in controlled attention. *International Journal of Bilingual Education and Bilingualism.*

Namazi, M. & Elin Thordardottir (submitted). Distraction by meaningful competing speech: A bilingual or working memory advantage. *Child Development.*

Nation, K., Adams, J.W., Bowyer-Crane, C.A., Snowling, M.J. (1999). Working memory deficits in poor comprehenders reflect underlying language impairments. *Journal of Experimental Child Psychology, 73,* 139-158.

Nation, K., Marshall, C.M. & Altmann, G.T.M. (2003). Investigating individual differences in children's real-time sentence comprehension using language-mediated eye movements. *Journal of Experimental Child Psychology*, *86*, 314–329.

Nelson, P., Kohnert, K., Sabur, S. & Shaw, D. (2005). Classroom noise and children learning through a second language: Double jeopardy? *Language, Speech, and Hearing Services in Schools, 36*, 219-229.

Oller, D.K., Pearson, B.Z., Cobo-Lewis, A.B. (2007). Profile effects in early bilingual language and literacy. *Applied Psycholinguistics 28***,** 191–230.

Paradis, J., Crago, M. & Genesee, F. (2005). Domain-general versus domain-specific accounts of Specific Language Impairment: Evidence from bilingual children's acquisition of object pronouns. *Language Acquisition, 13,* 33-62.

Paradis, J., Crago, M., Genesee, F., & Rice, M. (2003). French-English bilingual children with SLI: How do they compare with their monolingual peers? *Journal of Speech, Language, Hearing Research, 46,* 113-127.

Pearson, B.Z., Fernandez, S.C., & Oller, D.K. (1993). Lexical development in bilingual infants and toddlers: Comparison to monolingual norms. *Language Learning, 43,* 93-120.

Ransdell, S., Barbier, M. & Niit, T. (2006). Metacognitions about language skill and working memory among monolingual and bilingual college students: When does multilingualism matter? *The International Journal of Bilingual Education and Bilingualism,. 9*, 728-741.

Rogers, C.L., Lister, J.J., Febo, D.M., & Besing, J.M. (2006). Effects of bilingualism, noise, and reverberation on speech perception by listeners with normal hearing. *Applied Psycholinguistics, 27*, 465-485.

Roid, G. & Miller, L. (1997). *Leiter International Performance Scale-Revised.* Wood Dale, IL: Stoelting Co.

Roncandin, C., Pascual-Leone, J., Rich, J.B., & Dennis, M. (2007). Developmental relations between working memory and inhibitory control. *Journal of the International Neuropsyhological Society, 13,* 59-67.

Rosen, V. M., & Engle, R. W. (1998). Working memory capacity and suppression. *Journal of Memory and Language*, *39,* 418-436.

Rosen, V. M., & Engle, R. W. (1997). The role of working memory capacity in retrieval. *Journal of Experimental Psychology: General*, *126*, 211-227.

Rowe, D. C., Jacobson, K. C., & Van den Oord, E. J. C. G. (1999). Genetic and environmental influences on vocabulary IQ: Parental education level as moderator. *Child Development*, *70,* 1151-1162.

Salameh, E.K., Hakansson, G., & Nettelbladt, U. (2004). Developmental perspectives on bilingual Swedish-Arabic children with and without language impairment: A longitudinal study. *International Journal of Language and Communication Disorders, 35*, 65-91.

Salameh, E.K., Nettelbladt, U., Hakansson, G., & Gullberg, B. (2002). Language impairment in Swedish bilingual children: A comparison between bilingual and monolingual children in Malmo. *Acta Peadiatrica, 91*, 229-234.

Salthouse, T.A. & Mitchell, D.R.D. (1990). Effects of age and naturally occurring experience on spatial visualization performance. *Developmental Psychology, 26,* 845-854.

Schul, R., Stiles, J., Wulfeck, B., & Townsend, J. (2004). How 'generalized' is the 'slowed processing' in SLI? The case of visuospatial attentional orienting? *Neuropsychologia, 42*, 661-671.

Semel, E., Wiig, E., & Secord, W. (2006). Clinical Evaluation of Language Fundamentals-Fourth Edition. San Antonio, TX: The Psychological Corporation.

Semel, E., Wiig, E., & Secord, W. (2004). Clinical Evaluation of Language Fundamentals-Preschool Second Edition. San Antonio, TX: The Psychological Corporation.

Service, E. (1992). Phonology, working memory, and Foreign-language learning. *The Quarterly Journal of Experimental Psychology, 45A*, 21-50.

Shah, P. & Miyake, A. (1996). The separability of working memory resources for spatial thinking and language processing: An individual differences approach. *Journal of Experimental Psychology: General, 125,* 4-27.

Slobin, D.I. (1985). Why study language acquisition crosslinguistically. In D.I. Slobin (Ed.) *The Crosslinguistic Study of Language Acquisition, Volume 1: The data,* (pp. 1-24). Hillsdale, NJ: Erlbaum.

Smith, C. (1980). The acquisition of time talk: Relations between child and adult grammars. *Journal of Child Language, 7,* 263-278.

Smith, L., Fagan, J. F., & Ulvund, S. E. (2002). The relation of recognition memory in infancy and parental socioeconomic status to later intellectual competence. *Intelligence*, *30*, 247-259.

Spaulding, T.J., Plante, E., & Vance, R. (2008). Sustained selective attention skills of preschool children with Specific Language Impairment: Evidence for separate attentional capacities. *Journal of Speech, Language, and Hearing Research, 51*, 16-34.

Stevens, C., Sanders, L., & Neville, H. (2006). Neurophysiological evidence for selective auditory attention deficits in children with specific language impairment. *Brain Research*, *1111*, 143-152.

Sundara, M., Polka, L., & Molnar, M. (2008). Development of coronal stop perception: Bilingual infants keep pace with their monolingual peers. *Cognition, 108*, 232-242.

Superlab for Windows 2.0. (2006). San Pedro: CA, Cedrus Corporation.

Suprenant, A.M. (1999). The Effect of Noise on Memory for Spoken Syllables. *International Journal of Pscyhology, 34*, 328-333.

Tun, P.A., O'Kane, G. & Wingfield, A. (2002). Distraction by competing speech in young and older adult listeners. *Psychology & Aging, 17,* 453-467.

Turkheimer, E., Haley, A., Waldron, M., D'Onofrio, B., & Gottesman, I. I. (2003). Socioeconomic status modifies heritability of IQ in young children. *Psychological science, 14,* 623-628.

Von Hapsburg, D., Champlin, C.A., & Shetty, S.R. (2004). Reception thresholds for sentences in bilingual (Spanish/English) and monolingual (English) listeners. *Journal of the American Academy of Audiology, 15*, 88-98.

Walker, D., Greenwood, C. R., Hart, B., & Carta, J. (1994). Prediction of school outcomes based on early language production and socioeconomic factors. *Child Development, 65*, 606-621.

Werker, J. F, Pons, F., Dietrich, C., Kajikawa, S., Fais, L. & Amano, S. (2007). Infant-directed speech supports phonetic category learning in English and Japanese. *Cognition, 103*, 147-162.

Westman, M., Korkman, M., Mickos, A., & Byring, R. (2008). Language profiles of monolingual and bilingual Finnish preschool children at risk for language impairment. *International Journal of Language and Communication Disorders, 43*, 699-711.

Willis, C.S. & Gathercole, S.E. (2001). Phonological short-term memory contributions to sentence processing in young children. *Memory, 4/5/6*, 349-363.

Windsor, J., Kohnert, K., Loxtercamp, A.L., Kan, P. (2008). Performance on nonlinguistic visual tasks by children with language impairment. *Applied Psycholinguistics, 29*, 237-268.

Wolfe, C. D. & Bell, M. A. (2004). Working Memory and Inhibitory Control in Early Childhood: Contributions from Physiology, Temperament, and Language. *Developmental psychobiology, 44,* 68-83.