THE ANATOMY OF THE BILINGUAL INFLUENCE ON COGNITION:
LEVELS OF FUNCTIONAL USE AND PROFICIENCY OF LANGUAGE

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Abstract

Previous research has shown that bilingualism had positive influence on nonverbal task performance, but had negative influence on verbal performance. To understand these diverging bilingual influences, this dissertation established specific bilingual experiences, confirmed the positive and negative influence on nonverbal and verbal performance in one bilingual sample and examined the contribution of the established bilingual experiences on verbal and nonverbal performance. One hundred and twenty bilinguals with different language backgrounds and forty monolinguals were given a battery of tasks that measured language background, spatial short-term memory, nonverbal reasoning skills, English vocabulary, nonverbal executive functions, verbal fluency and sentence grammaticality judgment.

In chapter 2, responses from language background questionnaires were analyzed in factor analysis. Two distinct but related bilingual dimensions were extracted: balanced usage of languages and English proficiency. The bilinguals were profiled into four subgroups based on the varying levels of these two dimensions. In chapter 3, the two groups with the most contrasting language experience, namely the balanced bilinguals with high English proficiency and monolinguals, were compared in verbal and nonverbal tasks to establish the positive and negative influence of bilingualism. In chapter 4, the other bilingual subgroups were included in the same analyses reported in chapter 3.

The general pattern in nonverbal tasks showed that the bilinguals who attained high level in both bilingual dimensions often showed the most efficient performance compared to other bilingual subgroups and monolinguals. The two bilingual dimensions

contributed partially to performance in the executive functions tasks. A different pattern of results emerged in verbal performance: English proficiency was the primary contributing factor to verbal performance, with balanced usage of languages showing no further enhancement. However, these findings were confined to the lexical retrieval task, and did not extend to syntactic judgments. In summary, bilingualism was shown to be a multifaceted life experience that had positive outcome in nonverbal executive functions, but negative consequence in verbal performance. The divergent results in verbal and nonverbal performance were products of the interplay between bilingual experiences, such as balanced usage and proficiency of languages.

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Chapter 1. An overview of bilingual influence on language and cognition

Introduction

With the increasing bilingual population worldwide, the consequences of bilingualism have elicited interest in both the general public and research areas, and they have been investigated in social, educational, linguistic and cognitive domains. The societal influence of bilingualism interacts with social status (Oller & Eilers, 2002), social context (Roberts, Irvine, Jones, Spencer, Baker & Williams, 2007) and even national economy (Christofides & Swidinsky, 1998). Academically, educators are concerned with the effectiveness of bilingual education in a linguistically-diverse classroom (Bae, 2007) as well as general attitudes towards education using heritage languages (Wright & Bougie, 2007). Both societal and educational consequences of bilingualism are influenced by non-individualistic factors (social class, education system) that normally interact with individual differences. Does bilingualism, as an extrinsic factor, mediate intrinsic individual differences? From the linguistic and cognitive domains, the intrinsic changes triggered by extrinsic experience of bilingualism can be examined.

Although bilingualism is normally understood as the ability to communicate using more than one language, the consequences of being bilingual can extend to a more general level beyond language. Several studies using nonverbal executive functioning tasks, which require resolution of conflict from a competing alternative, have found that bilingual individuals performed significantly better than their monolingual peers (see review in Bialystok, 2001; 2007a). The authors' interpretation of the bilingual advantage in these studies was that the experience of regularly using two language systems and the need to manage attention to those two languages enhanced a general cognitive control mechanism.

Unlike the cognitive advantage in executive functions, the influence of bilingualism on linguistic tasks is mixed. Bilingualism is associated with weaker performance in tasks that require word retrieval, such as picture-naming (e.g., Gollan, Montoya, Fennema-Notestine & Morris, 2005) and verbal fluency (e.g., Gollan, Montoya & Werner, 2002). Moreover, bilinguals reported more occurrences of the tip-of-the-tongue phenomenon than monolinguals when it was experimentally induced (e.g., Gollan & Acenas, 2004; Gollan & Silverberg, 2001). However, other studies have reported no difference between monolinguals and bilinguals in verbal fluency (e.g., Portocarrero, Burright & Donovick, 2007; Rosselli, Ardila, Araujo, Weekes, Caracciolo, Padilla & Ostrosky-Solís, 2002). The only reliable bilingual effect found in linguistic performance is smaller vocabulary size in both languages spoken by bilinguals. Bilinguals have usually been reported to have weaker receptive vocabulary knowledge than their monolingual peers (Bialystok & Feng, in press; Oller, Pearson & Cobo-Lewis, 2007; Portocarrero, Burright & Donovick, 2007), although this could be confounded with whether the language of interest was the bilinguals' first or second language. With a smaller vocabulary size, it was not surprising to see bilinguals to perform lower on lexical retrieval tasks. The mixed results on bilinguals' performance in word retrieval tasks could be a reflection of bilinguals' smaller vocabulary size, which is only part of their bilingual experience.

Taken together, the evidence found on bilingual influence in cognitive and linguistic domains seems to be contradictory. Bilingualism seems to have positive and negative impact on cognitive and linguistic performance respectively. Therefore, the interaction between language and cognition can be examined through bilingualism because of its opposing influence on language and cognition respectively. If bilingualism is the source of the superior performance in executive functioning tasks, then which experiences of bilingualism is needed to elicit this advantage in executive functioning? Language processing also requires cognitive processes such as executive functions (e.g., Hernandez & Meschyan, 2006; Rodriguez-Fornells, De Diego Balaguer & Münte, 2006). If bilingualism enhances executive functions, then it would influence bilinguals' language processing by two opposing forces – the positive force via executive functions and the negative force via language proficiency. Can the interaction between these two forces be the explanation of the occasional disadvantage in bilinguals' language processing? If so, what are the magnitudes of these forces? These questions are important because understanding how specific linguistic experience affects general cognitive mechanisms sheds light on the nature of cognitive functioning in humans. The present dissertation sets out to examine the basis of the bilingual influence observed in verbal and nonverbal task performance from cognitive, psycholinguistic and neuropsychological approaches.

The first section of this chapter reviews literature on bilingual influences on language and cognition. The literature examines the influence of bilingualism by comparing the performance of monolinguals and bilinguals. From this review of bilingual influence, it is apparent that participants included in these studies also differed in their bilingual experience. The heterogeneous bilingual samples across all these studies could possibly account for the mixed results of bilingualism on language and cognition. Therefore, it is essential to establish an operational definition of bilingualism, isolating characteristics of bilingualism that demonstrate an advantage on cognition from those that do not. Instead of considering bilingualism as a categorical variable, this dissertation views bilingualism as a dynamic and multi-dimensional construct.

Since bilingualism reflects a daily experience of managing two language systems, it is essential to investigate specific processes involved in bilingualism from the psycholinguistic literature. Therefore, the second section of this chapter reviews some of the relevant psycholinguistic models that pertain to bilingualism. Although the general psycholinguistic literature tends to examine the cognitive or linguistic influence of specific languages or how two languages interact at different linguistic levels (e.g., lexicon, phonology and syntax), the present review focuses on identifying language-general processes that are common to all bilinguals. This approach is taken because the bilingual advantages on cognitive process, especially executive functions, are often observed in heterogeneous bilingual groups who speak different languages (except for Costa, Hernández & Sebastián-Gallés, 2008). This observation suggests that there is an overall cognitive advantage due to bilingual experience that is not language-specific, although the magnitude of this advantage could be influenced by the homogeneity of bilingual samples.

From the psycholinguistic literature, the activity of handling two languages is analyzed and decomposed into more specific processes. The bilingual processes reviewed in the psycholinguistic literature apply to all bilinguals, regardless of which pair of languages they speak. Following the identification of these bilingual processes, the next part turns the focus to the cognition literature to isolate cognitive processes that are comparable to those bilingual processes identified in psycholinguistic models. Finally, neuroimaging evidence suggests a common neurological network responsible for bilingual language processing and executive functions (Abutalebi & Green, 2007). Both linguistic and cognitive processes are proposed to converge on this common neurological network, explaining the connection between language and cognition in the brain. In turn, the experiential and neurological factors relating to bilingualism that contribute to the cognitive advantage and disadvantage in nonverbal and verbal executive functions are isolated.

The present dissertation aims to isolate the specific nature of elements that are responsible for the bilingual influence observed in verbal and nonverbal task performance. From the cognitive and psycholinguistic approaches, it is hypothesized that degree of functional use in two languages exerts control over the two language systems productively and has a positive relationship with nonverbal executive functioning performance that demands high levels of cognitive control. However, this relationship is also influenced by a bilingual's language proficiency level because language usage and language proficiency are related (Cummins, 1991). In other words, the bilingual advantage in nonverbal executive functioning is expected to be dependent on the amount of practice (functional usage) in controlling two language systems and proficiency of at least one of the two spoken languages; while performance in verbal tasks is expected to vary primarily as a function of language proficiency, and secondarily as a function of usage. The differential roles of functional usage and proficiency of language are expected to be the sources of the bilingual advantage in nonverbal executive functions and the mixed performance in verbal tasks. In order to identify features of bilingualism, specific bilingual experiences that were relevant to language and cognition need to be identified. The next section in this chapter reviews how bilingualism affects cognition and language and how the influence of bilingualism is connected to psycholinguistic models that address specific processes involved in bilingualism.

Influences of bilingualism on cognition and language

An early report of a bilingual advantage in cognitive functions found that bilingual five-year-old children were better than monolinguals at solving tasks of object constancy, naming and use of names in sentences (Feldman & Shen, 1971). This advantage was strongest in task components that relied on comprehension, which referred to providing a nonverbal response, but did not occur in production, in which a verbal response was required. This study is unique because it provided evidence that countered the then popular notion that bilingualism had a negative impact on general intelligence, verbal mental tests and school achievement (Barke & Williams, 1939; Darcy, 1953; Jones & Stewart, 1951; Macnamara, 1966; Mitchell, 1937; Saer, 1923; Smith, 1923, 1931). The early findings of a bilingual disadvantage in intelligence tests and academic achievements were largely due to the fact that the bilingual children were from immigrant families and often had lower social economic status (SES). Moreover, the achievement tests used in these studies were constructed on the basis of samples from middle-class children who were more comfortable with the standardized testing format. Barke (1933) compared Welsh-English speaking bilinguals to Welsh monolinguals (SES favoured bilinguals in this study) and found that bilinguals performed better than the monolinguals in nonverbal intelligence tests. However, when he conducted a follow-up study attempting to control for SES by recruiting children in "comparable" neighbourhoods (comparability was not explicitly defined), there was no difference between monolingual and bilingual children in nonverbal intelligence performance but a strong bilingual disadvantage in a vocabulary test. Therefore, early comparisons between monolingual and bilingual children were confounded with many social factors that interacted with bilingualism due to social factors: bilingual children were immigrants and they were often tested in their second language.

Feldman and Shen's (1971) study was more empirically valid because they recruited monolingual and bilingual children who attended the same school and classes. This recruiting strategy controlled somewhat for SES, so the confounding effect of SES on bilingualism was not as serious as in previous studies. Also, the tasks employed were Piagetian-based and focused on features of objects rather than paper-pencil-based standardized tests. Two interesting patterns in Feldman and Shen's (1971) study were: (1) the bilingual advantage was very clear in task components that did not require a verbal response; and (2) the bilinguals' performance in task components that required verbal responses were unclear. More than 30 years later, these two patterns persist in bilingual research. Therefore, the following sections aim to address the inconsistency between two lines of evidence in bilingual research.

Cognitive and linguistic advantages associated with bilingualism

Bilingualism and cognitive development

The magnitude of the bilingual influence on executive functions changes across the lifespan (Bialystok, 2007a; Craik & Bialystok, 2005). The positive influence of bilingualism is most apparent in childhood (about 4-7 years of age) and older adults (from 50-70 years of age); evidence for a bilingual advantage is limited in young adults, who are functioning at their highest levels. Relative to the amount of research on bilingual influences during childhood, there is much less on old age.

Children growing up in a bilingual environment in principle encounter two labels for the same object, e.g., the labels *dog* and *chien* both refer to the animal with four legs that barks. Both spoken and written words are symbolic representations of referents, so this experience may enhance children's flexibility in dealing with symbolic representations. Young children who were starting to learn the association between meaning and print allowed researchers to study this development. Indeed, words are symbolic representations of referents. It has been shown that bilingual children's experience of encountering two labels (one in each language) for the same referent helped them in a task that measures concepts of print. Concepts of print are a set of concepts that signify the functions of printed words. To assess the development of concepts of print, Bialystok (1999) devised a *moving word task* to specifically tap into young children's understanding of meaning constancy in printed words. First, the child is shown a picture of an object, e.g., a cup, and the experimenter discusses this picture with the child. A second picture, e.g., a dog, is presented and a brief discussion of that picture follows. Then a card that says *dog* is introduced, the experimenter explicitly names the word on the card to the child, and this card is placed underneath the picture of a dog. The child is asked the introductory question, "What does this card say?" Since the label on the card has just been introduced and it is placed under the dog picture, the child is very likely to say, "dog". At this time, an interloper enters the scene and "accidentally" pushes the card that says *dog* to the cup picture. The experimenter comments on the mess that the interloper has made and asks the question, "What does this card say?", the second time. After the child responds, the experimenter cleans up the "mess" by returning the printed card to the dog picture. Then the same question is asked the third time.

Generally, preliterate children provide the correct answer for the first and third questions, when the printed card is placed physically closer to its referent. However, preliterate children usually have the misconception that the meaning of the printed word changes when it is placed with another referent (Study 1 in Bialystok & Senman, 2004; Collins & Robinson, 2005). Therefore, they answer the second question incorrectly because of two reasons: (1) moving the card (need understanding of constancy of meaning to resolve); and (2) the closer proximity of the distracting picture (need control of attention to resolve). Moreover, this misconception persists even when the words are written in front of the child (Bialystok & Martin, 2003) and when the written representations of the words are less abstract than alphabets (Bialystok & Luk, 2007). In general, both monolingual and bilingual children's performance almost reaches ceiling in the first and third questions and their performance does not differ. However, bilingual children outperform monolingual children in responding to the second question; evidence indicates that this is because of their higher control of attention required to answer the second question correctly (Bialystok, 1997, 1999; Bialystok, Shenfield & Codd, 2000). From children's performance in solving the moving word task, it was shown that bilingual children were either more advanced in understanding concepts of print, better at controlling their attention to ignore the distracting picture, or both. Further evidence is required to isolate these two advantages observed in bilinguals.

In addition to advantages in emerging concepts of print, bilingual children have also been shown to be better at isolating representation from reality and solving false-belief tasks. Goetz (2003) compared a group of Mandarin-English bilingual children to a group of Mandarin monolingual children and a group of English monolingual children in a series of theory of mind (ToM) tasks and reported that three and four year old bilingual children outperformed both groups of monolingual children of the same age. Her explanation was that bilingualism facilitates inhibitory control and metalinguistic awareness. However, with the linguistically homogeneous bilingual samples (English-Mandarin), it was possible that the advantage in ToM tasks was due to the specific linguistic representation of mental states in Mandarin. Goetz (2003) addressed this possibility by including the two homogeneous monolingual groups. If Mandarin language representation is the source of the advantage in ToM, then the Mandarin-English bilingual group should perform similarly to the Mandarin monolingual group.

Since this was not observed, it was valid to attribute the ToM advantage to bilingualism. Nonetheless, ToM has a sociolinguistic property and the advantage could be a consequence of the Chinese cultural background because of the cultural emphasis on self-control (Oyserman, Coon, & Kemmelmeier, 2002). To strengthen the evidence that it is the bilingual experience, not the cultural background, that leads to advanced ToM, it is essential for the bilingual advantage be observed in a bilingual sample with diverse cultural backgrounds but similar language usage experience.

In an appearance-reality task (e.g., a sponge painted to look like a rock), Bialystok and Senman (Study 2, 2004) found that bilingual and monolingual children (3-5 years old) responded equally well to a question that concerned the appearance of the object in which there was no conflict between what the child saw and the correct response. However, on the reality question, in which the appearance and the correct response conflicted, bilingual children provided more correct responses than monolingual children after vocabulary performance was controlled. The interpretation of this finding is that bilingual children are more advanced than monolinguals in controlling their attention and better at ignoring misleading information (the appearance of the object). However, this bilingual advantage was observed only after bilinguals' lower receptive vocabulary level was accounted for. Since the bilingual children in Bialystok and Senman's (2004) study were from diverse linguistic backgrounds (hence diverse cultural backgrounds), the bilingual advantage cannot be attributed to a unique cultural experience. Unlike Goetz (2003), Bialystok and Senman (2004) interpreted the bilingual advantage as a result of advanced inhibitory control to ignore distracting information and not a general stronger mental representation of objects.

Bilinguals' advanced ability to ignore conflicting information was also detected in the ambiguous figures task. An ambiguous figure is a drawing that can be perceived in two ways. The most common ambiguous figures are composed of two areas of contrasting colours, usually black and white, e.g., two facial profiles placed so that they can be interpreted as either two faces facing each other or a vase in the middle. Gopnik and Rosati (2001) examined the developmental trend of the ability to perceive the dual identities of the ambiguous figures. The general results suggested that three- and four-year-old children did not perceive the alternative figure *even* when they were told of its existence, but a significant proportion of five-year-olds did successfully reverse the figures. These children's performance also significantly correlated with their performance in a false-belief task. Gopnik and Rosati (2001) speculated that a mechanism needed to successfully reverse these ambiguous figures relates to general conceptual understanding that one entity can be two representations simultaneously. The late development of perceptual reversal could also be a consequence of later development of higher-cognitive functions, such as executive functions or inhibition (Doherty & Wimmer, 2005; Gopnik & Rosati, 2001).

Bilingual children encounter objects being represented in multiple ways on a daily basis. As mentioned before, for French-English bilinguals, the four-legged animal that is furry and barks can be represented as *dog* or *chien*. With this experience in language, would bilingual children begin perceptual reversal earlier than their monolingual peers?

Bialystok and Shapero (2005) presented a series of ambiguous figures similar to the face-vase figure described earlier to six-year-old monolingual and bilingual children. First, these children were asked to identify the figure they saw in the picture (usually one of the two standard alternatives). Subsequently, the experimenter provided systematic guidance for the children to identify the other alternative in the picture. Unlike Gopnik and Rosati (2001), who reported children's performance as binary data, a performance score was given to reflect the amount of guidance given before the child identified the alternative. The less guidance provided, the higher the score. Quantifying amount of guidance allowed parametric comparisons. The pattern of results was very clear. Bilingual children outperformed monolingual children on three of the four ambiguous figures. The only figure that did not elicit a group difference showed the trend that bilingual children required less help; this figure was "easier" to reverse due to its perceptual nature and both groups of children approached ceiling. Bialystok and Shapero (2005) attributed the bilingual advantage to the bilingual children's advanced control of attention to the specific features of a figure that allow successful perceptual reversal.

The suggestion that bilingual children benefited in control of attention rather than having more sophisticated mental representation was also examined in the dimensional change card sort (DCCS) task (Bialystok & Martin, 2004). In the DCCS task, the child is given a stack of cards to sort with pictures that vary physically on two dimensions, usually shape (e.g., circle and square) and colour (e.g., red and blue) (Zelazo & Frye, 1998). If half of the pictures depict red circles, for instance, the other half show blue squares. The child is first asked to sort the cards according to one dimension, e.g., shape.

This is called the pre-switch condition. The number of cards correctly sorted according to the specified category (circle or shape) is recorded. After sorting all the cards, the experimenter asks the child to sort the card again, but this time, according to the other dimension, i.e., colour. This is called the post-switch condition and the numbers of cards correctly sorted is again recorded. Before the age of four, children may perform poorly in the post-switch condition (sort by colour) because they perseverate on the pre-switch rule (sort by shape), even after they are told explicitly that the rule has been changed. Bialystok and Martin (2004) manipulated the level of representation in the dimension of the pictures printed on the cards. The first pair of dimensions was perceptual-perceptual (colour-shape), the next pair perceptual-semantic (colour-object, e.g., blue trucks and red flowers) and the last pair conceptual-semantic (function-location, e.g., things can be worn or played and things that go inside or outside of a house). In the post-switch condition, it was found that bilingual children sorted more cards correctly than their monolingual peers in the perceptual and perceptual-semantic but not the conceptual-semantic dimensions. The results were taken to support the notion that a bilingual advantage occurred in post-switch performance (inhibitory control of distraction, i.e., pre-switch rule) on dimensions that encode perceptual information but not abstract conceptual information (i.e., bilingual children were not better at representing dimensions at a higher conceptual level).

A recent study conducted by Carlson and Meltzoff (2008) examined the extent of the bilingual advantage in executive functions in a group of kindergarteners. Spanish-English bilinguals, English monolinguals and English monolinguals learning a second language were given a battery of nine executive functions tasks. After controlling for differences in chronological age, verbal ability, and parents' education, bilingual children achieved a higher composite executive function score than the other two groups. The comprehensive battery of executive function tasks allowed the authors to examine which component of executive functions was influenced by bilingualism. To examine the nature of the executive function composite, they conducted a principal component analysis and extracted two orthogonal components that they labeled as conflict and delay. Although both components were executive, the Spanish-English bilinguals outperformed the other two groups on the conflict but not the delay component. From the group comparisons in conflict and delay, it was apparent that bilingual children attained higher performance in executive functions once their disadvantages in verbal ability and other possible confounds were statistically controlled, but only in conditions that required resolving conflict.

From studies comparing bilingual and monolingual children, it was found that bilingual children were more advanced in solving problems relating to concepts of print (Bialystok, 1997, 1999; Bialystok, Shenfield & Codd, 2000), appearance-reality isolation (Study 2 in Bialystok & Senman, 2004; Goetz, 2003), cognitive flexibility (Bialystok & Martin, 2004) and executive functions that involve conflict resolution (Carlson & Meltzoff, 2008). One common characteristic of the task conditions in which a bilingual advantage was found is the requirement to inhibit distracting information presented as an alternative response in tasks that do not require processing of linguistic stimuli. For example, the distracting picture in the moving word task and the appearance of the object in the appearance-reality task are both distracting stimuli presented *at the same time* as the stimuli that hint at the correct response. Solving these problems successfully requires the ability to inhibit or ignore distraction. Another observation is that bilingual children performed similarly to monolingual children in conditions that require analysis of knowledge about the task situation (e.g., the third question in the moving word task and the appearance question in the appearance-reality task). In Bialystok and Martin (2004), the bilingual advantage was found in conditions that required inhibitory control and this advantage was confined to dimensions that required encoding of perceptual information (when both alternatives are visible in the stimuli) and did not extend to encoding information at a higher level (when both alternatives are accessible through conceptual encoding of perceptual stimuli). The bilingual advantage, as suggested by Bialystok (1993), was observed to be most apparent in conditions that demand control, but not analysis. Does the advanced control ability in bilingual preschool children extend to school performance such as literacy and problem solving? The answer to this question is positive.

While historical studies primarily reported a bilingual disadvantage in school achievement tests and intelligence tests, a few reported a potential bilingual advantage (Ben-Zeev, 1977; Feldman & Shen, 1971; Peal & Lambert, 1962). Ben-Zeev (1977) found that American and Israeli Hebrew-English bilingual children outperformed American English-speaking and Israeli Hebrew-speaking monolingual children in four subtests of the Wechsler Intelligence Scale for Children (WISC: similarities, digit span, picture completion and picture arrangement). The bilingual advantage was observed in spite of the bilingual children's lower vocabulary level relative to their monolingual peers. Ben-Zeev (1977) controlled for SES by choosing children whose parents had similar levels of occupation and education. With the bilingual children's advanced performance on nonverbal WISC tasks, it is also reasonable to hypothesize that bilingualism has a positive impact on nonverbal reasoning. Bialystok and Majumder (1998) found that in a nonverbal problem-solving task, balanced French-English bilinguals performed better than their monolingual and unbalanced Bengali-English bilinguals. All the children were about eight years old. The balanced French-English bilinguals were fluent in both English and French while the unbalanced Bengali-English bilinguals were dominant in English with only partial knowledge of Bengali. These results partially replicated an earlier report in which both balanced and unbalanced French-English bilinguals outperformed English monolinguals in tasks that required control of processing (Bialystok, 1988).

Bilingualism and language development

Bilingualism is an experience that involves handling languages. Does this experience have any positive influence on children's language development? Findings from this area of research are slightly more perplexing than the findings reported for preschool children and school-age children's performance on nonverbal tasks. Bilingual advantages have been reported in phonological awareness (Chiappe, Glaeser & Ferko, 2007; Rolla San Francisco, Carlo, August & Snow, 2006), morpho-syntactic development (Demont, 2001), and lexico-semantic production (Sheng, McGregor & Marian, 2006). In phonological awareness, the reported bilingual advantages are usually found in bilingual children who speak two languages that have similar grapheme-phoneme correspondence (for example, Italian-English: D'Angiulli, Siegel & Serra, 2001; Spanish-English: Bialystok, Majumder & Martin, 2003; Hebrew-English: Geva, Wade-Woolley & Shany, 1993; Cantonese-Mandarin: Chen, Anderson, Li, Hao, Wu & Shu, 2004).

Although phonological awareness tasks do not necessarily recruit written representations of language, the phonological structures between languages are usually more similar if both languages have similar relations in grapheme-phoneme correspondence. For instance, both Italian and English are represented by alphabets and each written word is made up of a string of individual graphemes that roughly correspond to the phonemes, while Cantonese and Mandarin are represented by characters and each written word is composed of symbols that correspond to the syllable rather than phoneme. Surprisingly, phonological awareness was also observed to transfer between two languages that are in different writing systems, for instance, between Cantonese and English (Gottardo, Yan, Siegel & Wade-Woolley, 2001; Luk & Bialystok, in press). These studies used tasks that were created to be parallel between the two languages and assessed performance in the same group of bilingual children. Without comparing them to monolinguals, it is not possible to determine whether their phonological awareness was better than monolingual children. Therefore, the cognitive implication of the bilingual advantage observed in phonological awareness is limited.

Influence of bilingualism in adulthood

From the literature review of bilingual advantage in childhood, it is apparent that bilingualism enhances cognitive abilities that demand paying attention to relevant information that aids in making a correct response. Surprisingly, there is no study examining the bilingual influence on language and cognition in adolescents. Therefore, the following studies reviewed investigated influence of bilingualism in adulthood (20 years or older). In adults, the bilingual advantage has usually been observed in the most difficult conditions of a task, i.e., conditions that require the highest level of attention and control of behaviour (Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok, Craik & Rucco, 2006; Bialystok, Craik & Ryan, 2006). Unlike children, adults' accuracy in performance is usually very high. Therefore, the time to make the correct responses is typically used to measure performance. Accuracy rate is considered as a supplementary measure to verify if there was any speed-accuracy tradeoff.

In Bialystok, Craik, Klein & Viswanathan (2004), monolingual and bilingual participants (ages range from 30 – 88) were given a computerized Simon task. In the Simon task, participants are required to respond to visual stimuli (press left button when a red shape is presented, press right button when a green shape is presented). Stimulus-response compatibility is interfered with by the spatial presentation of the visual stimuli, which is irrelevant to the responses associated with the visual stimuli but distracting (Simon & Ruddell, 1967). Congruent trials are characterized by the congruence between the correct response and the position in which the stimulus is presented, for example, a red shape presented on the left (irrelevant spatial presentation provides *facilitating* information), and incongruent trials by incompatible spatial presentation, for instance, a red shape presented on the right (irrelevant spatial presentation provides *conflicting* information). Prepotent response for the bivalent stimuli is the irrelevant spatial presentation while the visual stimuli encode information for correct responses. The Simon effect is the difference in response time between congruent and incongruent trials. In other words, the Simon effect is the cost in response time when the irrelevant spatial presentation interferes with the preparation for correct responses. Overall, the Simon effect was smaller in the bilingual and in younger adults (20-30 years old). A similar but more exaggerated observation was seen in the older participants (55 years and older). This implies that younger and older bilingual participants were less disrupted than similarly aged monolinguals by the irrelevant spatial presentation of stimuli even though spatial presentation is the prepotent response for visual stimulus.

In a later study that involved an adapted version of the Simon task (Bialystok, 2006), the only statistically significant difference in the Simon effect between monolingual and bilingual young adults (20-30 years of age) was in the most difficult condition, in which a high degree of switching between congruent and incongruent trials was required. In addition, the influence of playing video games was investigated in the same study. To perform well on these cognitive tasks relied on selective attention and visual search, and video gaming experience has been shown to enhance such skills (Castel, Pratt, & Drummond, 2005; Green & Bavelier, 2003). Therefore, it was important to examine if the enhancement in cognition is similar between bilingualism and video gaming experience. Bialystok (2006) found that the effect of bilingualism was independent of the participants' experience in playing video game. While video game experience had a more global effect on solving the Simon task, in that video players were faster in all conditions, the bilingual advantage was specific to conditions that posed the highest level of conflicting information (the direction of the arrow pointing to and the spatial presentation are conflicting) and were the most complex (when switches between congruent and incongruent trials were high), hence the conditions that required the highest level of control of attention. When the congruent and incongruent trials were presented in a block with low-switches, i.e., there was a high probability of getting the same trial consecutively, there was no bilingual advantage. The Simon task was also adapted for five-year-old children (Martin-Rhee & Bialystok, 2008) and a similar pattern was observed: bilingual children were faster than monolingual children in both congruent and incongruent trials.

In the Simon task, the conditions in which the bilingual advantage was observed in adults were similar to those that showed the bilingual advantage in children. In both developmental periods, the bilingual advantage was found in task conditions that do not require processing of verbal information, but rather active control of attention to relevant information and ignoring distracting information. In the adult research, the bilingual advantage has not always reached statistical significance, although a trend is often observed. In fact, the bilingual advantage is usually confined to task conditions that embed the highest level of conflicting information. Using a modified antisaccade task, Bialystok, Craik and Ryan (2006) also found a bilingual advantage in response time. An antisaccade task adopts the similar phenomenon of the Simon task and imposes response rules to prevent participants from complying to prepotent responses. In all cases, relative to their monolingual peers, bilingual younger (average 20 years old) and older (average 70 years old) adults were less disrupted than comparable monolinguals by the presentation of stimuli that required response reversal, switching between tasks and inhibitory control. More importantly, when participants completed this task in an eye-tracker in which their eye movements instead of key presses were recorded, the language group difference disappeared in each age group.

The pattern of results was interpreted as evidence for similar processing speed in eye movements (or orienting their visual attention) between language groups. Coupled with the behavioural difference between monolinguals and bilinguals in response time using the same task, a bilingual advantage was found in the time required to make a correct behavioural response, but not in the time required to direct or control their eye movements. Another result was that the bilingual advantage was not observed in conditions in which only one type of trial was presented, although it was apparent when different types of trials were mixed together. Therefore, given the lack of language group differences in directing eye-movements towards a stimulus, the bilingual advantage observed in behavioural response time cannot be attributed to faster eye-movements. Instead, the advantage reflects the shorter time needed to make a correct response and effectively "execute" a decision to provide adequate responses.

Another line of research examines whether monolingual and bilingual adults differ in performance when they have to manage two tasks concurrently. The dual-task paradigm is often used to assess the additional processing demand when two tasks require immediate attention simultaneously over a single task. In one variation of the dual-task paradigm, one of the tasks is designated the primary task and the other is secondary; performance is usually lower when participants need to attend to both the primary and secondary tasks. The demand in divided attention is reflected in longer response time or more errors in the primary task. The measurement of performance in the secondary task is often used as a control measure to ensure that participants are attending to both tasks instead of just the primary task. Using picture classification as primary and secondary tasks, Bialystok, Craik and Ruocco (2006) found that bilingual younger (about 22 years old) and older (about 64 years old) adults sorted more pictures in a given period of time than their age-matched monolingual peers. There were three other variables in addition to the between-language group factor: modality (visual or auditory), domain (symbolic: letters/numbers vs. semantic: animal/musical instruments) and relatedness (whether the domain of cards are related or not in the two modalities). Bilinguals classified more cards in the symbolic but not the semantic domain. The authors speculate that animals and musical instruments are two distinct semantic categories while letters and numbers are overlearned symbolic concepts that do not require higher-order interpretation when performing the classification. Given the domain difference in representation, it is possible that bilinguals are more effective in managing an automatic task even when a secondary task shared some of the attentional resources. However, bilinguals and monolinguals performed similarly when the primary task required higher cognitive level processing, such as semantic categorization. In this case, the task at hand is not as automatic and the secondary task imposes increased cognitive demand.

Based on the primary task performance (Bialystok, Craik & Ruocco, 2006), it is sufficient to observe a bilingual advantage in the condition that does not require associating a semantic category to the presented stimuli. However, by giving the participants explicit instructions to focus on the primary task, it is possible that the participants solved the tasks by prioritizing the primary task rather than solving two tasks simultaneously. Therefore, the unbalanced attention placed on the two tasks does not reflect bilinguals' performance in handling two simultaneously active tasks. Moreover, perceiving the tasks through two modalities and outputting the response through the other two modalities (visual perception of pictures were responded to by pressing a button; auditory perception of sounds were responded to verbally) may entail too much cross-modality transfer. This transfer across modalities could possibly involve processes that do not relate to language which, in turn, dilute any differences between bilingual and monolingual groups. Therefore, it is essential to examine bilingualism and task switching by means of managing two task sets conceptually and responding to both tasks through the same input and output modalities. To investigate the bilingual effect on conceptual management of two task sets, the task switching paradigm was adopted.

The dual-task paradigm provides evidence that bilinguals are less disrupted than monolinguals in performing a primary task even when a secondary task is included to divert their attention. However, is this management of attention limited to (1) managing attention to different modalities; or (2) managing attention to both tasks in mind? In a task switching paradigm developed to address this question (Bialystok & Viswanathan, 2004), participants were given a stimulus that encoded two kinds of information, for example, a red cat provides information on colour and animal type. They were asked to respond to one of these two dimensions based on a cue provided simultaneously with the stimulus. If they saw a colour wheel, then they needed to respond with the colour of the stimulus. In the red cat example, the correct response would be "red"; if they saw an abstract blob, they needed to identify the animal name, e.g., "cat". In this paradigm, flexibility to switch between tasks (respond with colour name or animal name) can be assessed. Moreover, with simply one modality for input (visual) and one modality for output (verbal), better performance can be attributed to managing two tasks simultaneously, not managing output modality.

Using this task switching paradigm, Bialystok and Viswanathan (2004) found that bilingual young (about 23 years old) and older (about 66 years old) participants were more effective than monolinguals in switching to and from one of the two task-sets in their mind. Switching conditions were mixed in the same block, which allowed contrasts between the performance of switching responses (motoric and lower in processing demand) and switching tasks (abstract and conceptual, also higher in processing demand). The bilingual advantage was observed when participants were required to switch tasks but not to switch responses, suggesting that the bilingual advantage was reflected in conceptual representations of tasks and the associated responses rather than in motor responses.

The tentative interpretation of the results from these studies is that bilinguals are better at resisting interference from distraction (Bialystok et al., 2004; Bialystok, Craik & Ryan, 2006) or another task (Bialystok, Craik & Ruocco, 2006) and diverting attention to one of two active task sets (Bialystok & Viswanathan, 2004). The former advantage follows from the evidence seen in children's research in which bilinguals are better at ignoring distracting information. The latter advantage has two possible underlying causes: (1) bilinguals may have stronger working memory representation of tasks (keeping in mind a specific task context); and (2) bilinguals may be more effective in managing their attention to one of the tasks and make correct judgments accordingly (controlling cognitive resources for online processing). Regarding the first explanation, there was no evidence suggesting bilinguals and monolinguals differ in any capacity measure of memory span, for example, repeating numbers or words with some simple manipulation (Bialystok et al., 2004; Bialystok & Feng, in press), digit span (Bialystok & Martin, 2004; Bialystok & Senman, 2004), and verbal working memory (Gutiérrez-Clellen, Calderón & Weismer, 2004; between bilingual children who were highly proficient in both English and Spanish). The second explanation implies that bilinguals are better at controlling their attention at an executive level instead of at the motor level, leading to more efficient responses to one of the two tasks. Since there is evidence showing bilinguals and monolinguals perform similarly in eye-movement tasks (Bialystok, Craik and Ryan, 2006), it is reasonable to rule out the possibility that bilingualism has a positive influence on controlling eye-movement. As a result, the bilingual advantage observed in the dual-task and the task switching paradigms both indicate an effective management of attention, which is the driving source of the advanced performance.

The bilingual advantage observed so far indicates that the advantage is at an abstract cognitive level of managing the tasks (deciding which feature of stimuli/task should be focused), not at a response level (deciding which button to press). If bilingualism affects the way an individual manages her attention in a situation, we should see the largest bilingual effect on cognition in terms of attention. Also, the bilingual advantage does not only lie in conditions in which conflict is presented. In a few studies (Bialystok, 2006; Bialystok et al., 2004; Martin-Rhee & Bialystok, 2008), the bilingual advantage was also observed in congruent conditions in which there is no conflict in the stimulus-response mapping. In these cases, bilinguals were not only better at inhibiting distraction, but also attending to facilitating information or switching between different stimulus-response mapping. Since the bilingual advantage was only observed in conditions that had congruent and incongruent trials intermixed, this finding could also be related to successful switching between the two types of trials. Regardless, the bilingual advantage observed in these cases has been found in heterogeneous bilingual groups whose members predominantly speak English and a variety of other languages. This suggests that the bilingual advantage is not specific to languages and is driven by a general mechanism that is commonly recruited by all bilinguals.

Costa, Hernández & Sebastián-Gallés (2008) followed this argument and examined if a homogeneous group of bilingual young adults (mean ages 22 years old) outperformed their monolingual peers in a response time task that taps into the three main processes involved in an attention network (Attention Network Task, ANT, Fan, McCandliss, Sommer, Raz & Posner, 2002). These three processes are alerting, orienting and executive control. The ANT combines the flanker paradigm (Eriksen & Eriksen, 1974) with a cue reaction time paradigm (Posner, 1980). Bilingual participants in Costa, Hernández & Sebastián-Gallés' (2008) study were all undergraduate students at the University of Barcelona who spoke Spanish and Catalan on a daily basis and had attained a high level of proficiency in both languages. Monolingual participants were Spanish speakers who did not function fluently in any other languages except for Spanish. The ANT is very simple and elegant. Participants are instructed to pay attention to a middle arrow and respond to the direction to which it is pointing (either left or right). This middle arrow is flanked by two distracters on each side. The distracters can be arrows pointing to the same (congruent) or different (incongruent) direction as the middle arrow, or dashes (no facilitating or distracting information is given, so it is a neutral). Different types of cues were also presented to elicit different types of attention.

The general results pointed to a bilingual advantage in alerting and controlling but not orienting attention. In the alerting network, bilinguals benefited more from the cues alerting them about the stimulus presentation. In the executive control network, bilinguals resolved conflict (induced by the incongruent flankers) more efficiently than the monolinguals. The most critical evidence is that the difference in response time between incongruent and congruent trials was smaller in bilinguals than monolinguals. This smaller difference suggests bilinguals were not as disturbed by the distracting flankers. Moreover, the bilingual effects were found to decrease as the participants accumulated more experience with the tasks. This result replicated Bialystok et al.'s (2004) finding that bilingual and monolingual participants converged to the same level of performance towards the end of the experimental session.

An overview of the bilingual advantage across lifespan

From the review on the advantage of bilingualism, it is clear that across all age groups tested, bilinguals are more advanced than their monolingual age peers in certain aspects of cognitive processing. Given that cognitive functions change across lifespan, it is inevitable that different tasks and measures are more sensitive to the monolingual-bilingual difference in performance across age groups. As a result, the bilingual advantage was observed in different dependent variables, e.g., proportion or number of correct responses, response time and accuracy. However, the diversity of observations adds to the validity of the argument for a bilingual advantage. Despite the diversity in bilingual advantage, there seems to be an observable pattern across tasks and development. First, bilinguals were better at performance in tasks that required a minimal level of linguistic analysis (e.g., appearance-reality task, ambiguous figures task, executive functions tasks, Simon task, and the antisaccade tasks). The moving word task and the task switching paradigm may have required participants to provide verbal responses, but the lexical retrieval demand in these tasks was minimal and automatic because all the required verbal responses were high in frequency and familiarity. The discussion on lexical retrieval is elaborated in the next section. Second, all the tasks that elicited a bilingual advantage involve some level of conflict between stimulus and response. For instance, in the Simon task, the conflict level is highest in the incongruent trials in which information conveyed by the stimulus (cue to response) and its position (irrelevant distracter) are incompatible (e.g., left-pointing arrow on the right side of the screen). Third, the bilingual advantage in adults was most observable when congruent (no conflict) and incongruent (conflict) trials were mixed together in the same block. In this case, bilinguals outperformed monolinguals in both congruent and incongruent trials (Bialystok, 2006; Bialystok, Craik & Ryan, 2006; Martin-Rhee & Bialystok, 2008).

When the trials were presented in separate blocks (Bialystok, Craik & Ryan, 2006) or in a low-switching trial condition (Bialystok, 2006), the bilingual advantage disappeared. This evidence suggests that bilinguals are more efficient in managing their attention when flexibility is required to respond correctly. Fourth, the bilingual advantage in cognition was often observed in a heterogeneous bilingual sample. Heterogeneity here refers to the languages that these participants spoke, not their experience. In fact, all the bilingual participants had similar language experience – they had all used two languages for the majority of their lifetime.

The finding that bilinguals across the lifespan outperformed monolinguals is interesting. However, an explanation is needed for this advantage. What is it in bilingualism that enhances an individual's ability to ignore distracting information? Moreover, bilingualism is a language experience and yet the positive effects of this language experience on cognition are mainly limited to nonverbal performance. It is undoubtedly the case that bilingualism also has an effect on language. Language processing is far more perplexing than simply sounding out letters or reading a word. From the general overview, bilingualism seems to have an overall negative impact on language, despite its positive influence on cognition. The next section addresses the disadvantages of bilingualism on language.

Linguistic disadvantages associated with bilingualism

Language development starts in infancy. Prior to acquiring language production skills, infants show speech perception skills that are essential to later speech development (Newman, Ratner, Jusczyk, Jusczyk & Dow, 2006). For example, Vouloumanos and

Werker (2007) confirmed that one- to four-day-old infants preferred to listen to speech sounds rather than analogous sine waves that were comparable in acoustic properties of speech sounds. It was also the researchers' interests to determine how early infants were able distinguish between their "native" language and foreign languages. Burns, Yoshida, Hill and Werker (2007) compared English monolingual and English-French bilingual infants' development of phonetic boundaries. The general results suggested that six- to eight-month old monolingual and bilingual infants showed a similar phonetic boundary for distinguishing two syllables with different voice onset time (VOT). This is evidence for a language-general speech perception mechanism during that stage of development. However, by 10 to 12 months, these infants had developed language-specific categorical perception of phonemes. By this age, they were sensitive to the different phonetic boundaries that occurred in English and French.

Following this finding, it is essential to compare monolingual and bilingual infants' speech perception development. Fennell, Byers-Heinlein and Werker (2007) recently examined speech perception and word learning abilities in infants (14, 17 and 20 months of age) from both homogeneous (English-Chinese and English-French) and heterogeneous (English-other languages) bilingual environments. From previous research, it is known that monolingual English infants start to use speech sounds as a tool for word learning between 14 to 17 months (Werker, Fennell, Corcoran & Stager, 2002). Using these monolingual infants' performance as a baseline, Fennell, Byers-Heinlein and Werker (2007) tested infants growing up in a bilingual environment. Regardless of the nature of bilingual environments, these infants were delayed in grasping speech cues as a tool for word learning. In general, across the homogeneous and heterogeneous bilingual samples, the infants did not acquire this knowledge until about 20 months. Fennell et al. (2007) suggested that this delay reflected the infants' increased cognitive load in assigning two labels to the same objects because in their bilingual environment, the mapping between referent-reference is not one-to-one. Furthermore, this delay showed that infants were able to understand how an object can be symbolically represented with two labels.

From infant speech perception research, it is evident that by 10 to 12 months, infants have developed language-specific phonetic boundaries for the language(s) they encounter in the environment (Burns et al., 2007). This early speech perception and word learning is shaped by experience, which is induced by stimulation in infants' immediate environment (Fennell et al., 2007). It is logical to assume that early speech perception and word learning differences in monolingual and bilingual infants would extend to early childhood language development, such as phonological awareness. More importantly, this development would also be affected by the specific languages that a bilingual child speaks. In the previous section reviewing the bilingual advantage, it was reported that in some studies, bilingual children outperformed monolingual children in phonological awareness (e.g., Bialystok, Luk & Kwan, 2005). This advantage was limited to bilingual children who spoke two languages that had similar grapheme-phoneme correspondence (GPC) and were represented similarly in a writing system (English vs. Spanish instead of English vs. Chinese).

In a study by Bialystok, Majumder and Martin (2003), English monolingual children, Spanish-English and Chinese-English bilingual children (six and seven years old) were compared on a range of phonological awareness tasks. The general results were that Spanish-English bilingual children outperformed monolingual children in phonological awareness in only one task. Chinese-English children performed worse than their English monolingual peers. It is possible that because Spanish and English are both represented alphabetically, there is a large degree of overlap in the process of reading between the two languages: reading both languages relies on sounding out letters. Chinese and English are represented using two very different writing systems. Although general phonetic structures are similar (syllables composed of phonemes organized into onset and rhyme, which can be further partitioned to nucleus and codas structures), each language relies heavily on different structures to encode meaning (e.g., English on graphemes, Chinese on characters). In addition, the task administered was a phoneme segmentation task. The sound structure of phonemes is not as transparent in Chinese as it is in other alphabetic languages. As a result, the Spanish-English bilinguals benefited from the similarity of the phonological structures in their two languages, while the Chinese-English bilingual children suffered from incompatible phonological structures.

As an extension to studying the effect that the writing system has on phonological awareness and early literacy, Bialystok, Luk and Kwan (2005) compared Spanish-English, Hebrew-English and Chinese-English bilingual children (six years old) to English monolingual children. Each of these bilingual groups spoke a language that deviates progressively from English. Both Spanish and English are written with the same script

(Roman alphabets) and are in the same writing system (alphabetic writing system). Although Hebrew and English are both alphabetic languages, the alphabets representing these languages are different (Roman for English, Semitic for Hebrew). Other than the difference in script, English and Hebrew also differ in writing direction (English from left to right, Hebrew from right to left). Therefore, except for the basic principle of reading in which letters mainly represent sounds, English and Hebrew differ in the symbolic representation of sounds. Finally, as mentioned before, Chinese and English use different scripts and are represented by different writing systems (Chinese as characters, English as alphabets). Unlike alphabetic writing systems in which only sound is represented, the Chinese writing system represents both meaning and sounds. To confirm the degree of similarity between these languages, a non-word decoding task was administered in both languages to all the bilingual children. The cross-language correlation for performance on this task was high between Spanish and English ($r = .72$), moderate between Hebrew and English ($r = .57$), and trivial between Chinese and English ($r = -.09$). These patterns remained after controlling for chronological age. The comparison of English phonological awareness across these language groups reflects the influence of writing systems: The Hebrew- and Spanish-English bilinguals outperformed the Chinese-English bilinguals and the English monolinguals.

In general, at least in biliterates, the bilingual influence on phonological awareness is constrained by the degree of similarity between writing systems represented in each of the two languages. The nature of bilingual influence is complex and may be mediated by other factors, such as instructional methods and proficiency in the two languages (Bialystok, McBride-Chang & Luk, 2005). Bilingualism delays speech-induced word learning ability in infancy and phonological awareness in childhood. Does this delay extend to vocabulary acquisition? Bialystok and Feng (in press) found that the answer was positive based on aggregated vocabulary performance of 963 monolingual and bilingual children between the ages of five and nine over a span of five years. Vocabulary performance was measured by the Peabody Picture Vocabulary Task (PPVT; Dunn & Dunn, 1981, 1997) and raw scores were age-standardized. The aggregated analysis showed that bilingual children had a lower English PPVT score across all age groups. These bilingual children all spoke English and a variety of non-English languages, but they were homogeneous in that all of them were educated in English and had their non-English languages as home languages.

This bilingual disadvantage in vocabulary was also found in Spanish-English bilingual children in a large-scale study conducted in Miami (Oller, Pearson & Cobo-Lewis, 2007). These bilingual children were given the PPVT (in English), the Test de Vocabulario en Imágenes, Peabody (TVIP; Dunn & Dunn, 1981; Dunn, Padilla, Lugo, & Dunn, 1986) and a series of subtests from the Woodcock-Johnson and Woodcock-Muñoz language and literacy battery in both English and Spanish (Woodcock, 1991; Woodcock & Muñoz-Sandoval, 1995). The general results confirmed a "bilingual profile effect" in which Spanish-English bilingual children were similar to their monolingual peers in some tasks (reading and writing) but worse in others (vocabulary and picture naming). The bilingual disadvantage in vocabulary and picture naming was especially apparent and it was consistent across bilingual groups with different SES, immersion programs and levels of home usage of Spanish and English. From the comparison between second- and fifth graders, the bilingual profile effect attenuated across time. Perhaps the bilingual disadvantage in proficiency-related measures (mostly receptive vocabulary) was observed because bilinguals' performance was always compared to English monolinguals and English may not have been the bilinguals' first language. An earlier study from the same group in Miami compared Spanish-English bilingual children's receptive vocabulary scores (PPVT & TVIP) to Spanish monolingual peers and found a similar bilingual disadvantage (Fernández, Pearson, Umbel, Oller & Molinet-Molina, 1992).

From three large-scale studies, it was obvious that there is a reliable and consistent bilingual disadvantage in vocabulary development across a heterogeneous sample (Bialystok & Feng, in press) and a range of homogeneous samples (Oller, Pearson & Cobo-Lewis, 2007). Receptive vocabulary performance required children to point to one of four pictures in response to a word produced by the experimenter. Bilingual children's lower receptive vocabulary performance can be attributed to their lack of knowledge for a particular concept in one language. However, bilingual children may know the verbal label for the designated picture in the other language. So it is possible that the bilingual children's lower performance reflects insufficient language labels for certain concepts, but not necessarily the concepts themselves. For instance, a French-English bilingual child may know the word *dog* for a four-legged-animal, but not *chien*. In this case, the child knows the concept of a dog, but fails to map the French label, *chien*, to the concept. Since receptive vocabulary was often measured in only one language, this particular measurement only provides insight on children's available labels for one language, but not their knowledge about concepts or ideas. Although research in developing "fair" assessments for bilingual children's vocabulary is very limited, one study stands out that supports the conclusion that bilingual children's lower vocabulary performance does not reflect a deficit in concepts.

Bedore, Peña, García & Cortez (2005) assessed Spanish-English bilingual children with different levels of dominance in English and Spanish in a bilingual task. No monolingual control group was included in the study, but the two groups that primarily spoke either English or Spanish were treated as "monolinguals" (who were essentially bilinguals with very unbalanced proficiency). This strategy was used because the authors intended to control for possible confounding factors such as SES and neighbourhood differences. Children were asked to describe some objects in English and Spanish, such as birthday cake, flower, dog and truck. Instead of the traditional scoring methods yielding separate English or Spanish scores (only score performance in either English or Spanish), Bedore et al. (2005) also scored bilingual children's responses regardless of the language of production. Conceptual scores were generated from the English and Spanish versions of the tests as the unique number of correct items in each language, ignoring which language was used to express a concept. In other words, the conceptual score was a measurement of the semantic understanding of a certain object, with minimal emphasis on its linguistic representations in one of the two languages that the bilingual children spoke. Based on these conceptual scores, the balanced bilingual children achieved similar performance to the unbalanced bilingual children in both Spanish and English. A similar finding was reported by Junker and Stockman (2002) in a small sample (n=10) of German-English bilingual toddlers. However, when bilingual children's vocabulary performance was scored in each language separately (Bedore et al., called these "monolingual scores"), bilingual children achieved scores lower than peers who were more proficient in either English or Spanish. This bilingual disadvantage was confined to the linguistic representation domain, and not found in the conceptual-semantic domain.

Vocabulary development also relies on a range of other cognitive processes, such as verbal memory (Ehri, 2005; Gathercole & Baddeley, 1989; Gathercole, Willis, Emslie & Baddeley, 1992). Is there a bilingual disadvantage in verbal memory that subsequently results in a bilingual disadvantage in receptive vocabulary performance? In another aggregated study comparing monolingual and bilingual children's (5-9 years old) memory span for words, no group difference was found (Bialystok & Feng, in press). A similar lack of difference was found in the digit span task administered in English (Bialystok, Luk & Kwan, 2005). The interpretation is that bilingual children do not differ from monolingual peers in their memory span, but they have a significantly smaller vocabulary pool. The smaller vocabulary size is unlikely to be a consequence of failing to remember words or associating labels to referents, and more likely a consequence of the increased cognitive demand of assigning two labels for the same concept. Nevertheless, this does not imply that a bilingual mental lexicon is the sum of two monolingual lexicons (Grosjean, 1989).

The majority of the research showing a bilingual disadvantage in vocabulary has been conducted with children; there is limited research systematically examining vocabulary in bilingual adults. In a recent study, Portocarrero, Burright, & Donovick (2007) compared monolingual and bilingual college students' vocabulary levels. These bilingual college students spoke English and a variety of other languages. Results confirmed a bilingual disadvantage in both receptive and expressive vocabulary tasks, measured by Peabody Picture Vocabulary Task (PPVT) and Expressive Vocabulary Task (EVT) respectively. Therefore, it seems as if there was an overall bilingual disadvantage in vocabulary, often measured in English. A similar bilingual disadvantage in English vocabulary was also found in children (4-6 years old) (Bialystok & Martin, 2004; Study 2 in Bialystok & Senman, 2004; Bialystok, Shenfield & Codd, 2000; Bialystok and Shapero, 2005), but not in younger (20-30 years old) and older (50-70 years old) adults (Bialystok et al., 2004; Study 2 in Bialystok, Craik and Ruocco, 2006). It was possible that these bilingual young adults were immigrants who arrived Canada at a young age or were born in an English-speaking country but spoke a heritage language at home. In either case, by the time they reached adulthood, English had become their dominant language and their English proficiency had reached highly proficient levels. English vocabulary as measured by PPVT or EVT was divergent, so it is possible that some such differential bilingual experiences affected the language proficiency outcome.

Bilinguals have also been shown to perform more poorly than monolingual peers on tasks that require lexical retrieval. Gollan and colleagues have shown that bilingual adults (20-30 years old) had lower performance than monolinguals in spontaneous word generation (verbal fluency) and confrontation naming (name pictures in black-and-white line drawing) and experienced more tip-of-the-tongue (ToT) phenomena. Verbal fluency and picture naming are benchmark clinical assessment tools for diagnosis of neurodegenerative diseases, such as Alzheimer's disease. Despite the growing bilingual population, there is relatively scarce research examining the effect of bilingualism on these standardized verbal measures. As a result, it was unclear whether bilingualism would lead to an inaccurate diagnosis of these diseases.

The most commonly used measure for confrontation naming is the Boston Naming Task (BNT, Kaplan, Goodglass, & Weintraub, 1983). The BNT consists of 60 line drawings depicting objects in black and white. Items are arranged in order of increasing difficulty. When the participant fails to provide a response, the experimenter can provide semantic and/or phonemic cues. However, only correct responses without cueing are credited. In studies reporting comparisons of monolingual and bilingual BNT performance, participants are usually given the whole range of pictures starting from the first one. This is more appropriate because standardization of the BNT was devised in a monolingual sample and may not apply to the bilinguals. In an attempt to generate a BNT norm for the Spanish-English bilinguals in the United States, Kohnert, Hernandez and Bates (1998) gave the BNT to 100 Spanish-English bilingual college students in both English and Spanish (same items for both languages). These students rated themselves fairly highly on both English and Spanish proficiency, but mainly used English (70% of estimated daily use) on a daily basis. Regardless of their high self-rated proficiency, their performance in naming the pictures in Spanish was much worse than their performance in English, indicating that they were more dominant in English relative to Spanish. In the item analysis, it was observed that the variability in proportion of correct responses was much greater for Spanish, suggesting the heterogeneity of individual differences in the weaker language for confrontation naming. Therefore, it confirmed the authors' concern that a separate norm needs to be developed for bilinguals for the BNT.

Roberts, Garcia, Desrochers and Hernandez (2002) compared English monolinguals, Spanish-English and French-English bilinguals' performance on the BNT in English. A strong bilingual disadvantage was observed using both strict and lenient scoring systems. The general pattern of results showed that both bilingual groups named fewer pictures than the monolinguals, with no difference between the two bilingual groups. The authors also noted that performance within the bilingual groups was highly variable and only a small proportion of the bilingual participants performed within one standard deviation of the English monolinguals' mean performance distribution. This finding echoes Kohnert, Hernandez and Bates' (1998) finding of greater variability in bilinguals' than monolinguals' performance, both at individual and item levels.

To further understand why the BNT generates a bilingual disadvantage even when bilinguals are allowed to answer in their dominant language, Gollan and colleagues examined whether the bilingual disadvantage lies in producing a label for the pictures or recognizing the picture in general. In Gollan, Montoya, Fennema-Notestine and Morris' (2005) study, instead of using the standard BNT with 60 pictures, 180 similar line drawings were chosen from Snodgrass and Vanderwart (1980) and presented as stimuli. Participants were asked to either name the pictures or classify them into one of two categories (human-made or natural). The general pattern of results indicated that although bilinguals named a similar number of picture correctly as monolinguals, they took longer to respond even when performing the task in their dominant language, i.e., English. However, the two groups classified pictures equally fast with the same accuracy rates when classification was done manually rather than verbally. In a following experiment, similar monolingual and bilingual participants were given more pictures. The purpose was to determine if repeated presentation would attenuate bilinguals' disadvantage at picture naming. The bilingual disadvantage in Study 1 was replicated: bilingual participants responded more slowly and made more errors than monolinguals. However, the difference in response time between bilingual and monolingual groups decreased as the presentation frequency of the pictures increased. The authors attributed the bilingual disadvantage in picture naming to both cross-language interference and less experience in using a particular language compared to monolinguals.

The bilingual disadvantage in picture naming also extends to old age. Gollan, Fennema-Notestine, Montoya and Jernigan (2007) compared balanced and unbalanced Spanish-English bilinguals (about 73 years old) in the BNT. The reported findings were that balanced bilinguals named fewer pictures than unbalanced bilinguals and benefited more from the methods of allowing word production in either their dominant or non-dominant language, i.e., either Spanish or English, whichever language came to mind when the picture was shown. When matched for item difficulty in terms of frequency, balanced bilinguals' performance in their dominant language was facilitated by cognate items, while the unbalanced bilinguals benefited from the cognate effect in their non-dominant language. Cognates are words in different languages with the similar form and meaning. For example, *flower* in English and *flor* in Spanish are cognate items (Gollan, Fennema-Notestine, Montoya and Jernigan, 2007).

In general, the bilingual disadvantage in confrontation naming extends from young adulthood to old age. Bilingual participants named pictures more slowly and less accurately than their monolingual counterparts. Gollan, Fennema-Notestine, Montoya and Jernigan (2007) interpreted the findings as evidence for bilinguals' less frequent lexical access in each of their languages compared to monolinguals (the Weaker Links Hypothesis is discussed in the following section), the consequence of which is costs in both speed and successful retrieval.

Spontaneous word generation does not require specific search for a linguistic label of an object in the mental lexicon. Does the bilingual disadvantage in picture naming extend to spontaneous word production? Comparing bilingual and monolinguals' performance on verbal fluency would provide some insights. Relative to the BNT, there is much less research investigating the bilingual influence on spontaneous word generation, or verbal fluency. Verbal fluency tasks typically involve two conditions, phonemic (or letter) fluency and semantic (or category) fluency (e.g., the Controlled Oral Word Accuracy Task, COWAS, Strauss, Sherman, & Spreen, 2006). The standard task requires participants to produce as many words as possible within one minute that satisfy a stated criterion. In the letter fluency condition, participants are asked to produce words that start with a given letter, excluding numbers, proper names, places or words in different forms; for example, if the response given is *work*, then *works, worked* or *working* should not be produced. In category fluency, participants are to produce words in a semantic category, e.g., animal or musical instrument, without the restrictions noted for letter fluency. In both conditions, repeated words are considered incorrect. The total score for each condition is the number of correct responses within the one-minute period.

Gollan, Montoya and Werner (2002) compared Spanish-English bilingual and English monolingual adults in letter, category and proper name fluency. The general pattern of results suggests lower bilingual performance in category fluency, but no difference in letter fluency. Surprisingly, bilingual participants even produced more correct responses in letter fluency, although the difference did not reach statistical significance. Results for proper name fluency were similar to those for category fluency. Rosselli, Ardila, Araujo, Weekes et al., (2002) compared English monolingual, Spanish monolingual and Spanish-English bilinguals and reported similar patterns of results in letter and category fluency performance. However, Rosselli et al. (2002) had very unequal sample sizes (45 English monolinguals, 18 Spanish monolinguals and 19 Spanish-English bilinguals) and a wide range of educational levels (from 2 to 23 years). With these problems in the design and subjects' individual differences, it is difficult to decide whether the reported results were confounded by these factors.

The two conditions in the verbal fluency task measure different mechanisms in word retrieval. Although there is no definitive evidence, psycholinguistic research suggests that the human lexicon is organized by both semantic connections (as shown in semantic priming studies), and by phonemic links (Miller & Fellbaum, 1991). However, generating words in the category condition is similar to accessing an item in interconnecting networks. This behaviour is similar to our daily activity, for instance, coming up with a list of items for grocery shopping or places to visit while vacationing in Italy. The items in the list are often related to each other semantically in a similar context. On the other hand, generating words in the letter fluency task is analogous to generating words in a phonemic category. This is more effortful because phonemic generation is not a common activity that we do everyday. Furthermore, the restrictions imposed on the letter fluency task also require additional executive control to avoid producing items that belong to the restricted lists. Certainly, letter fluency performance requires relatively more executive control than category fluency. The dissociation between letter and category fluency was also observed in participants performing these tasks in functional magnetic resonance imaging (fMRI) (Paulesu, Goldacre, Scifo, Cappa et al. 1997). These authors showed that when performing letter and category fluency tasks silently, the distinct activation area for letter fluency was the posterior opercular area of Broca's area (third inferior frontal gyrus), but both fluency tasks activated the anterior triangular area of Broca's area and left thalamus. This finding confirms that letter fluency demands more cognitive resources and these demands are confined in the left frontal area, which was also recruited in cognition tasks free of language production (Yeung, Nystrom, Aronson, & Cohen, 2006).

From reviewing the bilingual influence on nonverbal executive control, it is apparent that bilinguals have enhanced cognitive control and often outperform their monolingual peers. If letter fluency recruits more cognitive control, then bilinguals should also be better at this task. However, this was not observed in the two studies reported (Gollan, Montoya & Werner, 2002; Rosselli, Ardila, Araujo, Weekes et al., 2002). Instead, in both studies bilinguals showed the same level of performance in letter fluency as monolinguals but a disadvantage in category fluency. One possible explanation of this pattern of results could be initial differences in proficiency between monolingual and bilingual participants. Successfully generating words in letter and category fluency conditions requires a certain level of proficiency in the language used to perform the task. Therefore, the bilingual disadvantage observed in the verbal fluency tasks could be due to: (1) lower proficiency in the task language; and/or (2) bilingualism. The disadvantage in bilingual children's language proficiency is well established (Bialystok & Feng, in press; Oller, Pearson & Cobo-Lewis, 2007). However, the English proficiency level of the monolingual and bilingual participants was not reported in Gollan, Montoya and Werner (2002) and Rosselli, Ardila, Araujo, Weekes et al., (2002). If bilinguals did not have the same language proficiency level as monolinguals, it is possible that they did not perform at monolingual levels in a language production task for this reason. Self-rated proficiency in English and Spanish was used to establish the bilingual participants' levels of bilingualism and proficiency. Without objective measures of proficiency independent of the fluency task, however, it is difficult to isolate these two explanations for the bilingual disadvantage in verbal fluency.

The opposing forces

In summary, bilingualism exerts two opposing forces on an individual. On the one hand, the experience of handling two languages facilitates the control of attention. This experience affects a language-general cognitive mechanism that allows bilinguals at all ages to outperform their monolingual peers in executive functions tasks. In other words, bilingual experience has a positive influence on executive functions. This mechanism is proposed to be language-general because positive influences can be observed in a heterogeneous bilingual group (heterogeneous refers to the languages that the bilinguals speak). In contrast, the demand to handle two mental lexicons proves to be a cognitive burden. As a result, bilingual individuals, especially children, often score lower on standardized vocabulary measures, even when the task is administered in their dominant or native languages. In young adults, bilinguals often fail to retrieve a lexical item as successfully as monolinguals.

Because these two opposing forces (positive nonverbal and negative verbal) have been observed in a heterogeneous group of bilinguals who speak different pairs of languages, it is logical to conclude that these forces are consequences of bilingualism, and not of a particular pair of languages that a bilingual speaks. To further investigate differential performance in executive control due to language experience, it is necessary to understand bilingual processes in the psycholinguistic literature and how these processes are recruited in cognition. The next section discusses bilingual models that are not confined to a specific group of bilinguals.

Psycholinguistic models of bilingualism

The process of constantly managing two languages requires a bilingual individual to engage mental activities that are not specifically related to language. These include paying attention to one of the two language networks, ignoring irrelevant linguistic information activated in the other network, and suppressing the habitual tendency to converse in a dominant language when the second language is needed. These processes do not entail any knowledge or understanding of a specific language. Regardless of which pair of languages is spoken, these processes are involved when that person manages two language systems. This part of the review explores the literature on the linguistic and cognitive factors that comprise bilingual experience. The emphasis of psycholinguistic research has been the mental organization of lexicons and concepts and the processes involved in accessing these constructs in a bilingual context.

In the Revised Hierarchical Model (RHM) (Kroll & Stewart, 1994), the asymmetrical strengths of the links between L1, L2 and concepts vary as a function of the fluency levels in L2. Level of fluency in L2 depends on how proficient a person is in spoken L2. In the Inhibitory Control (IC) model (Green, 1998), a control mechanism is responsible for handling the two languages. This control mechanism does not operate on the amount of knowledge in either L1 or L2; instead, it operates to achieve a goal and allocates different amounts of attentional resources to either language network. Similarly, the Bilingual Interactive Activation + (BIA +) model (Dijkstra & van Heuven, 2002) suggests a mechanism that controls attentional resources allocated to one of the two language networks. In the BIA + mode, this mechanism allows a bilingual to efficiently manage the two languages and access the appropriate language depending on the situation. To explain the lower language performance that is often observed in bilinguals, Gollan, Montoya, Cera & Sandoval (2008) have proposed a weaker links hypothesis. This hypothesis points to the lower frequency of using words in each of the languages spoken by bilinguals as the source of their lower performance. Commonalities among these models may shed light on the underlying processes involved in bilingualism.

Revised Hierarchical Model (RHM, Kroll & Stewart, 1994)

The general consensus among psycholinguistic researchers was that concepts were shared between languages; the centre of debate was whether the lexical systems between languages were shared or separate (see Dong, Gui, & MacWhinney, 2005 for evidence of a shared network; Forster & Jiang, 2001; Marian, Spivey, & Hirsch, 2003 for evidence of separate networks). The RHM was devised using evidence from picture naming and translation between L1 and L2 in a variety of bilinguals. Early hierarchical models of bilingualism suggested that bilinguals stored words and concepts in two different levels (Snodgrass, 1984). Memory for words in each language was stored separately in two lexical systems while memory for concepts was stored abstractly and was common to both lexical systems. Further research suggested that bilingual lexical acquisition was more complicated. For fluent bilinguals who had established a fair level of proficiency in both languages, both their first language (L1, language that is acquired first) and second language (L2, language that is acquired after the acquisition of L1) had direct access to concepts because naming pictures in L2 was similar to that in L1 (Kroll & Curley, 1988). For non-fluent bilinguals who had not established a stable lexical system in L2, accessing concepts through L2 had to pass through L1. As a result, their response time to access concepts through L2 was longer (Kroll & Curley, 1988). Kroll and Curley (1988) suggested that a concept mediation model (direct access to concepts via L1 and L2) fit the performance of highly proficient fluent bilinguals, but a word association model (L2 access to concept must pass through L1) fit the performance of non-fluent bilinguals. Importantly, there was a developmental shift of behaviour as a function of proficiency.

A closer look at the data presented by Kroll and Curley (1988) showed an interesting pattern. Participants were asked to name words, and to translate words and pictures in L1 and L2 under two conditions: (1) items organized in semantic categories; and (2) items randomly mixed. Fluent bilinguals (concept mediators) were expected to benefit from the organized lists because of the semantic organization. However, results showed that all bilinguals took longer to name the semantically organized pictures than the random list in their L1. In other words, fluent bilinguals showed semantic interference rather than facilitation. One confounding factor in the Kroll and Curley (1988) study is that the semantically organized and mixed lists were levels of a between-subject factor. To ensure that individual differences did not mask category interference, Kroll and Stewart (1994) conducted three further experiments on bilingual memory organization. The RHM was built upon these three experiments.

The major objective of experiment 1 was to replicate the category interference found in Kroll and Curley (1988) using a within-subject design. The picture naming paradigm adopted was simple: 120 objects from 12 semantic categories were presented as both line drawings and English words. Each participant was asked to name pictures or read words in semantically organized and randomized lists. Semantically organized lists included two to four categories presented in sequence. Randomized lists included items from the 12 semantic categories. The results indicated that the response time required to name pictures was longer in the semantically organized list than in the randomized list. However, response time to read words was unaffected by the nature of the lists. These findings support the notion that category interference occurs in picture naming. Experiment 2 examined whether category interference was at the lexical activation level or at the conceptual activation level. The procedure was similar except that words and pictures were presented in an alternative sequence instead of in blocks of either words or pictures, as they were in Experiment 1.

Alternating the presentation modes should retain the demand for lexical activation but diminish the demand for conceptual activation. In fact, word reading does not often require accessing concepts, e.g., the Dual-Route Cascaded DRC model was based on reading words through the non-lexical route without passing through the semantic system (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). Based on this manipulation, two competing predictions were made: First, if category interference occurred at the lexical activation level, then regardless of the manipulation, category interference should still be observed because the demand of assigning a lexical item to a word/picture is the same in Experiment 1 and 2. Second, if category interference occurred at the conceptual level, then the alternation would eliminate category interference observed in Experiment 1 because level of demand fluctuated in conceptual activation but not in lexical activation. Lack of category interference in alternating words and pictures would suggest that the source of this interference was conceptual, not lexical. Findings were consistent with the second prediction: There was no category interference when participants were asked to name words and pictures alternately. There was a cost in response time associated with reading words in the alternate trials, but not in the response time taken to name pictures. Kroll and Stewart (1994) concluded that continually accessing related concepts produces interference (more activation) at the conceptual level, which makes it harder to find a matching lexical item.

From the results of Experiments 1 and 2, Kroll and Stewart (1994) speculated that two diverging processes govern identifying words and identifying pictures, thus indicating separate paths to the lexicon and to access concepts via lexical items. The results were extended in Experiment 3 to examine the implication of category interference in bilingual translation. The main goal of Experiment 3 was to examine the relationship between concepts, and the L1 and L2 lexical systems. In addition, the direction of translation from L1 or L2 was also noted to be asymmetrical. From unpublished data, Kroll and Stewart (1994) noticed that participants often took longer to translate from L1 to L2. This difference was stronger in less fluent bilinguals, i.e., when the asymmetry between L1 and L2 proficiency was greater. The authors hypothesized that translation from L1 to L2 involves concepts as mediators, but translation from L2 to L1 is solely lexical-based and bypasses concepts because of the larger number of lexical items available in the more proficient L1. If concepts are not mediators, the time it takes a bilingual to translate from L2 to L1 should be shorter. The RHM proposed by Kroll and Stewart (1994) is an information processing model that takes into account proficiency level in L1 and L2 in the context of lexical and conceptual access. Moreover, access and representations of L1 and L2 are affected by proficiency levels of the two languages (as the size of semantic networks) and how they interact in translation.

Inhibitory Control Model (ICM, Green 1998)

The RHM explains the processes required to access L1 and L2 representations as a function of the strengths of language representation. But how is the process of accessing L1 and L2 representations controlled? Are there higher cognitive mechanisms that manage the usage of L1 and L2? If the control process is limited only to the language level, then the process of selecting either language as response can possibly be tagged, but a mechanism is still needed to decide if the language tags should be chosen or not. Therefore, a cognitive mechanism needs to be in place to manage the two language systems and decide which one should be used to produce an output. As an extension of the RHM, Green (1998) proposed the ICM, which hypothesizes a language-general cognitive mechanism for effective management of L1 and L2 production by maintaining active task goals (responding in L1 or L2).

Based on the attention model in controlling motor actions devised by Norman and Shallice (1986), Green (1998) proposed that the control process for handling two languages is much like the control process for motor action. In general, language input is received by the bilingual lexico-semantic system. However, language output is not instant. The bilingual lexico-semantic system interacts with a conceptualizer, which is responsible for constructing concepts by recruiting information from long term memory. This conceptualizer is similar to the concept pool in RHM. The task of using either language as output is framed as language task schemas. Schemas were defined as "mental devices or networks that individuals may construct or adapt on the spot in order to achieve a specific task and not simply to structures in long-term memory." (Green, 1998, p. 69). Both concepts (conceptual) and language task schemas (intentional) are mediated by the Supervisory Attention System (SAS), which is constantly regulated by the active task goal. These processes focus primarily on management of attention and cognitive resources to solve the task at hand. After selecting a language as output, the bilingual lexico-semantic system represents concepts or ideas in their respective language and produces verbal output. In the ICM, the conceptualizer, SAS, language task schemas and task goal are all represented at the cognitive level independent of languages. Languages are represented in the bilingual lexico-semantic system which receives (decodes) and produces (encodes) verbal information into respective languages. The ICM was effectively an expansion of Kroll and Stewart's RHM that takes into account the asymmetry level of proficiency between L1 and L2.

In general, the ICM views bilingual processing as competition between two alternative responses. Moreover, the two languages are constantly activated in a bilingual mind. To resolve the competition to respond in one of the two languages, a language-general cognitive system, namely the SAS, actively inhibits lexical items with the unwanted language tags. Similar to the RHM, the ICM represents word forms and meaning at two different levels. However, the involvement of a language-general control mechanism extends the ICM's application in the bilingual translation process. RHM states that naming pictures in L2 must pass through the route to naming the picture in L1 provided that L2 proficiency is lower than L1 proficiency. However, RHM does not fully explain how a bilingual can avoid naming the picture in L1 when it is, indeed, being translated first. The ICM explains bilinguals' ability to produce a specific language at will as the product of an inhibitory control mechanism. Moreover, it is because of this inhibitory control mechanism that a bilingual is able to code-switch between two languages. Interestingly, while the RHM explains the asymmetry between translation performance between L1 and L2 as a function of proficiency, the ICM suggests that bilinguals' successful use of both languages owes to the inhibition of language tags in the bilingual lexico-semantic system (similar to the mechanism described in RHM) and at the level of the language task schema (which is at a cognitive planning level not addressed in RHM). In other words, in addition to the role of proficiency suggested in RHM, Green (1998) suggested that managing two languages did not limit at the linguistic level and that the representation of resolving the conflict between two language systems occurs at a cognitive level (relating to control of attention).

Both the RHM and the ICM portray bilingual processes that apply to bilinguals who speak different pairs of languages but analyze bilingual processing from two different angles. The RHM, stemming from the picture naming paradigm, relates bilinguals' access to concepts and subsequent naming in either language to L1 and L2 proficiency. It successfully explains the asymmetrical performance in time taken to naming pictures in L1 and L2 in an information processing approach. The ICM elaborates and extends the experience of processing two languages to include general cognition. The SAS in the ICM is responsible for controlling which language to use as the output channel. Processes at this decision-making level are not influenced by L1 or L2 proficiency because the mechanism is language-general or, as Green (1998) stated, non-linguistic. The RHM and the ICM highlight two fundamental mechanisms that make bilingual language processing effective and possible: proficiency from RHM and inhibitory control from ICM.

Other bilingual models from psycholinguistics

Bilingualism has also been studied in a connectionist framework. Dijkstra and van Heuven (2002) proposed the Bilingual Interactive Activation + (BIA +) model, developed from visual word recognition research in computational modeling. An important feature of the BIA+ model is that it is strongly influenced by Green's (1998) ICM, especially the ideas of task schemas and SAS, the attentional control mechanism. In fact, the ICM and an earlier version of the BIA+ (namely, BIA) complemented each other: The ICM focuses on bilingual language *production* while BIA focuses on bilingual *comprehension* (Green, 1998). The major difference between the BIA and ICM is that linguistic and non-linguistic mechanisms are differentiated more explicitly. According to Dijkstra and van Heuven (2002), the task schema in BIA+ was directly adopted from Green's (1998) ICM. To reiterate, task schema were non-linguistic processors responsible for planning and organizing steps needed to resolve the task at hand. At the linguistic level, because BIA+ focuses on the word recognition process, different systems are devised to be responsible for semantics, lexical and sublexical processing at the phonological and orthographical levels. These components make up the linguistic processing layer. Activation at this layer pertains to linguistic processing and involves lexemes (according to Dijkstra and van Heuven, *lexeme* refers to *visual word form* in BIA+) as the embarkation point of the process.

The non-linguistic layer is somewhat similar to the task schema in the ICM. Dijkstra and van Heuven (2002) proposed that word recognition is a bottom up process and that it is lexemes that guide the information flow. At the non-linguistic layer, task schemas are responsible for adapting to a decision-making criterion. Interestingly, the task schema in BIA+ was not proposed to inhibit the unwanted language. Instead, Dijkstra and van Heuven (2002) suggested that it is impossible to "inhibit" one of the two highly activated languages because parallel activation of lexemes (from bottom-up process) is very strong, even when the language is not needed for a response. The task schemas reflect participants' expectation and task demands, rather than a language-general control mechanism. Nevertheless, the main feature of BIA+, as devised from bilingual word recognition studies and connectionist models, is that bilingual processing does not only involve linguistic processes, but also control of attention to a target language -- a feature of the ICM as well. The process of controlling attention may not entail any linguistic information. This notion is similar to Green's ICM in which a bilingual individual's task was defined in two steps: at the control level to decide which language is in use and at the schema level to handle the lexico-semantic system in different languages. Green and Dijkstra and van Heuven considered ICM and BIA+ to be complementary of each other rather than contradictory. While ICM focuses on bilingual language production, BIA+ focuses on comprehension.

The psycholinguistic models of bilingualism reviewed in this section provide some ideas regarding the control of the two language systems in bilinguals. Both BIA+ and Green's ICM hypothesized that control of languages occurs hierarchically, at levels beyond the linguistic representations. If management of the successful usage of each language was language-general (and all bilinguals needed this control to manage when to use which language efficiently), then the bilingual advantage observed in the nonverbal executive functions research could possibly be a by-product of the management of two linguistic systems. This would explain the positive force in bilingualism: control of language gives rise to cognitive advantage. However, these models offer limited explanation for the well-established observation that bilinguals are relatively poorer in lexical access or retrieval (often measured by picture naming or verbal fluency), even in their first or dominant language (e.g., Gollan & Acenas, 2004; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Gollan, Montoya, & Werner, 2002; Ivanova & Costa, 2008). One recently proposed psycholinguistic model that focuses on the bilingual disadvantage in language tasks is the "weaker links hypothesis" (Gollan, Montoya, et al., 2005; Gollan, Montoya, Cera, & Sandoval, 2008). In this hypothesis, Gollan and colleagues suggest that given the same amount of language usage, bilinguals need to divide their time, cognitive resources and energy between two language systems, so their use of each language is less than monolinguals.

The weaker links hypothesis was developed on the assumption that lexical representations of a verbal label would become stronger with accumulated experience or usage of a language. Since bilinguals spend less time on each of their languages compared to their monolingual peers, lexical representations in each of their languages (even their dominant language) would be substantially weaker than lexical representations in monolinguals. In addition, bilinguals' weaker lexical representation would be especially apparent in low frequency words because the "weaker links" between semantics (concept) and phonology (name of the object) would be even more fragile in words that were not used often (e.g., braid, knot, apron, crutches). Gollan, et al. (2008) confirmed the weaker links hypothesis by comparing monolingual and bilingual young adults in a picture naming tasks. English monolinguals, Spanish-English balanced and unbalanced bilinguals were asked to name the presented pictures as quickly as possible in either English or Spanish alone. Their results were in accordance with previous research showing that bilinguals were slower and more error-prone in naming pictures than their monolingual peers, with the unbalanced bilinguals even slower and committing more errors. The pattern of results was exaggerated in low frequency items. When comparing English and Spanish in the bilingual groups, response times were slower and more affected by the frequency of the items in the non-dominant Spanish relative to the dominant English.

The weaker links hypothesis provides a plausible explanation for the well-established lower performance in picture naming in bilinguals. With bilinguals' use in either language being less than monolinguals, they build up weaker links between the semantic-phonology relations in each language. This weaker relationship would be most apparent in a picture naming task in which participants are required to name the presented pictures as fast as possible. Previous findings indicated that the bilingual disadvantage was limited to lexical access (or naming) of a picture, but not found in identifying and classifying the pictures (Gollan, Montoya, et al., 2005). Therefore, the weaker links hypothesis points to a plausible explanation for the fact that bilinguals performed poorly in language tasks: their lexical networks were not as available as those of monolinguals.

The weaker links hypothesis provides an explanation for the picture naming disadvantage in bilinguals. However, bilinguals have been shown to be poorer in proficiency as well (Bialystok & Feng, in press; Portocarrero, Burright, & Donovick, 2007). Could the weaker links hypothesis be extended to explain the lower proficiency level of bilinguals? Bilinguals' language proficiency level is often measured via receptive vocabulary. In a typical receptive vocabulary task, such as the *Peabody Picture Vocabulary Task* (PPVT-III, Dunn & Dunn, 1997), participants are required to choose one of the four line drawings that best describe a word produced by the experimenter. The process leading to a correct response would be the reverse of that involved in naming a picture: Bilinguals would have to first identify the word produced by the experimenter in the corresponding lexicon storing the word (usually administered in English), then activate a semantic network or concepts relating to the word stimulus. Finally, they would have to make a decision based on similarity between the concepts they have created in their mental lexicon to the presented pictures. If, according to the weaker links hypothesis, bilinguals had weaker representations of phonology-semantics relations in their respective languages, then bilinguals would be expected to perform more poorly because they would fail to connect the word with the associated concepts. This hypothesis was based on the assumption that the connection between phonology and semantics is bi-directional. In this case, bilinguals' lower performance in proficiency is not due to lack of concepts (Bedore, et al., 2005) but rather to weaker association between phonology and concepts. This speculation based on the weaker links hypothesis could potentially explain the bilingual disadvantage in language proficiency, although empirical support is currently lacking.

Revisiting the opposing forces in bilingualism

From the psycholinguistic point of view, bilingual language processing potentially involves proficiency levels in L1/L2 (RHM and weaker links hypothesis) and a general control mechanism that manages attentional resources to one of the two languages (ICM). The RHM (Kroll & Stewart, 1994) addresses the relationship between concepts and verbal labels for concepts in L1 and L2. In this model, proficiency is a prominent factor because how a concept is labeled verbally changes as a function of proficiency. The RHM captures both picture naming and translation processes in bilinguals and evaluates bilingual processes in terms of proficiency in L1 and L2. In the weaker links hypothesis, bilinguals' lower performance in picture naming was hypothesized to be a consequence of a weaker connection between phonology and semantics due to lower frequency of use. Both the RHM and weaker links hypothesis provide compelling explanations for the bilingual disadvantage observed in verbal tasks. The ICM (Green, 1998) extends bilingual processes beyond the linguistic domain and suggests that a language-general cognitive mechanism manages attentional resources and inhibits the unwanted language to avoid confusion in production. In the ICM, the language-general cognitive mechanism resolves competition that arises between different language task schemas. Based on the

ICM, a general cognitive mechanism beyond language processing is necessary for bilingual processing.

In order to understand why bilingualism enhances performance in nonverbal executive functions but shows mixed results in verbal executive functions performance, both proficiency in the language of the task administered and cognitive control mechanism(s) unrelated to levels of linguistic knowledge need to be considered. Overall, from psycholinguistic models, two driving forces, namely linguistic proficiency and non-linguistic cognitive control mechanisms, interact to influence bilingual processing. These two driving forces lead to the divergent and inconsistent results from bilingual research. The negative driving force pulls bilinguals lower in performing language tasks while the positive force pushes them higher in performing the nonverbal cognitive tasks. The review of the psycholinguistic models provides an insight on the bilingual processes that could explain the bilingual disadvantage in verbal tasks. The next section addresses the characteristics of executive functions and relates bilingual processes that are similar to those in executive functions in order to examine the bilingual advantage in nonverbal executive functions.

Models of executive functions

The bilingual processes proposed by some psycholinguist models are similar to nonverbal processes that are generally called executive functions. When engaging in complex cognitive tasks (language systems management being one of them), a set of specific cognitive processes involved in controlling and coordinating multiple activities in order to achieve a specific goal falls under the term “executive functions”. Miyake, Friedman, Emerson, Witzki and Howerter (2000) defined executive functions as a set of control mechanisms that are not confined in any domain. These mechanisms play a role in all processes in human cognition. There is no unified theory of the exact components in executive functions (Alvarez & Emory, 2006); but in general, theories of executive functions concern individual differences in the ability to control the amount of attention placed on a specific task (selective attention, Posner & Rothbart, 1998), ignore irrelevant information (inhibition, Miyake et al., 2000), and delete unnecessary information to allow more efficient processing of relevant information (updating, Miyake, et al., 2000). These processes could be unique or overlapping. Investigating the nature of these constructs is beyond the scope of this paper. The important point is that if these processes are general in purpose, they could apply to language processing. Therefore, it is possible that these mechanisms are recruited when a bilingual manages two language systems. This section focuses on the discussion of executive functions from Miyake and colleagues (Friedman & Miyake, 2004; Miyake et al., 2000), Shallice and colleagues (Norman & Shallice, 1986) and Posner and colleagues (Fan, McCandliss, Somer, Raz & Posner, 2002; Posner & Rothbart, 2007). These three areas of work were chosen because the mechanisms described were most similar to the processes discussed in the bilingual models reviewed in the previous section of this chapter.

Miyake et al. (2000) examined three distinct but related subprocesses of executive functions: (1) shifting, (2) updating, and (3) inhibition (of prepotent response). Shifting was defined as the shifting of mental set in terms of tasks context, e.g, responding to one dimension of stimuli such as colour and shifting to respond to another dimension, such as shape. Updating was the process of replacing critical information in working memory to facilitate responses for a current task. Of these three subprocesses, shifting and inhibition of prepotent response are relevant to bilingual processing. The current review of bilingual advantages in cognition indicated that bilinguals perform better in situations that demand inhibition. Moreover, in the ICM, Green (1998) proposed that it is the control of an inhibitory mechanism that allows bilinguals to converse flexibly in either one of their two languages. However, the inhibitory control mechanism described in ICM seems to be more concept-based than Miyake et al.'s (2000) motor-based one. The three bilingual tasks that loaded on Miyake et al.'s (2000) inhibition factor were antisaccade tasks, a stop-signal task and a stroop task. All these tasks required inhibition of prepotent responses but were also confounded with the need to inhibit an active concept that was in competition to bias the motor response.

In the psycholinguistic literature, it is agreed that the two language systems in a bilingual's mind are constantly activated (e.g., ICM and BIA+). This has been reported in studies recruiting bilinguals in eye-tracker tasks (Blumenfeld & Marian, 2007), fMRI and ERP (for review, see Rodriguez-Fornells, De Diego Balaguer, & Münte, 2006). Moreover, the two language systems in bilinguals have most often been observed via lexical processing (Schwartz & Kroll, 2006; Sunderman & Kroll, 2006; Thierry & Wu, 2007). In consequence, successfully speaking in one of their two languages requires bilinguals to inhibit the unwanted language. Shifting and updating may also be involved in bilingual processing. Shifting can be related to bilinguals' ability to shift their attention between two language systems, producing seamless conversation in one language, even if the other language was active and interfering. This construct is similar to the SAS in Green's ICM. Updating, in Miyake et al.s' (2000) interpretation, refers to monitoring and updating information stored and being processed in the working memory. Since bilinguals and monolinguals were found to have similar span level in memory (Bialystok & Feng, in press), it is not expected that bilinguals' representation of memory would be greater than that of the monolinguals. Moreover, it was uncertain whether individual differences lie in working memory capacity or working memory processes. Updating was a process that combined both capacity and processes. Therefore, it was hard to make a prediction of bilingual influence on updating based on current findings on working memory.

Collectively, in Miyake et al.'s (2000) framework, the subprocess "inhibition" seems to be related to bilingual processing and bilingualism was expected to affect this subprocess of executive functions. The other subprocesses, updating and shifting, may be influenced by bilingualism but the magnitude of their influence is expected to be smaller because they do not significantly overlap with bilingual processes as identified in psycholinguistic models. Friedman and Miyake (2004) examined *inhibition* to isolate potential subprocesses within it. Using confirmatory factor analysis, they proposed three factors: resistance to proactive interference, prepotent response inhibition and resistance to distraction. The latter two factors were found to be closely related but neither correlated with resistance to proactive interference.

In Miyake and colleagues' framework, bilinguals should be better at resisting the urge to perform a prepotent response and resisting distraction. This was especially apparent in the Simon task (Bialystok, Craik, et al., 2004; Bialystok & De Pape, submitted; Martin-Rhee & Bialystok, 2008) in which participants were requested to refrain from responding to the spatial location of a cue and respond only to the direction of an arrow (or colour of a square). Success on this task requires resisting both prepotent responses (responding to the more salient spatial location cue) and distraction. In terms of proactive interference, empirical evidence showed that bilinguals were less affected than monolinguals by items shown in previous lists of words, although this difference was marginally statistically significant and found only in children (Bialystok & Feng, in press). In Miyake and colleagues' terms, bilingual children showed a stronger advantage in prepotent response inhibition and resistance to distraction and a relatively weaker advantage in proactive interference. The weaker advantage in proactive interference may have been owed to the bilingual children's lower vocabulary scores and the resulting difficulty in retrieving lexical items.

What is the control mechanism that coordinates and manages cognitive resources for carrying out actions at will? Norman and Shallice (1986) proposed a Supervisory Attentional System (SAS) as the sole source of attention control. SAS is also the source of attentional control in Green's (1998) ICM, i.e., a special case of Norman and Shallice's (1986) attention model specific to bilingual language processing. In Norman and Shallice's (1986) model describing the control of behaviour, action sequences were organized by two types of control mechanism: controlled and automatic. The controlled mechanism was effortful and was required when faced with novel or complex tasks. The automatic mechanism was a consequence of practicing a set of processes for a long time and the control of processes becoming relatively effortless. One of the criteria for tasks that require controlled attention is that they should "require the overcoming of a strong habitual response or resisting temptation" (p. 3). Further, controlled attention does not only suppress unwanted actions, but also facilitates wanted actions. From these descriptions, it could be implied that when facing two competing alternatives for actions, such as when bilinguals are faced with conversing in two language systems, controlled attention (as one subprocess in SAS) allows bilinguals to use one of the two languages at will.

An important note of Norman and Shallice's (1986) attention model is how skill level affects vulnerability to interference between competing tasks. Norman and Shallice (1986) referred to Allport's (1980) example, that highly competent pianists showed no interference when asked to sight-read and perceive speech at the same time. Applying this notion to bilinguals, it is expected that highly proficient bilinguals would show less interference than monolingual peers when performing dual tasks (Bialystok, Craik & Ruocco, 2006; Bialystok & Viswanathan, 2004).

However, being a highly proficient bilingual can have different meanings. First, a highly proficient bilingual can be a person who speaks both languages fluently but only in a limited context, which could be related to the level of usage in both languages. For example, a foreign student studying in Canada might use English on a daily basis and speak the language fluently but still produce sentences with grammatical errors. Alternatively, a highly proficient bilingual can refer to someone who knows both languages well and could produce both languages at native levels but whose language knowledge does not relate to usage. In the present dissertation, being a proficient bilingual refers to having a high level of lexical knowledge as measured by receptive and expressive vocabulary tasks.

Normally, a bilingual would show asymmetry in level of knowledge between the two languages because the amount and context of exposure differ during the acquisition of the two languages. Typically, knowledge (or fluency) is stronger in L1 than L2, since linguistic knowledge for L1 is expected to be at a native level. Therefore, proficiency, in terms of bilingual processing, is expected to reflect the proficiency level of the second language. If a bilingual attains comparable levels of proficiency in L1 and L2, s/he would be considered as a proficient bilingual. According to Norman and Shallice (1986), being proficient (or skillful) would avoid interference in the face of distraction or the need to divide attention. Proficiency assessed this way has been shown to modulate bilinguals' performance in tasks that require constant switching between languages in a linguistic context (e.g., Elston-Güttler, Paulmann & Kotz, 2005; Reiterer, Hemmelmann, Rappelsberger & Berger, 2005). Therefore, it is reasonable to expect proficiency to be part of the bilingual experience that affects bilinguals' performance in executive function tasks that do not require language processing. If SAS (Green, 1998; Norman & Shallice, 1986) is truly domain-general, then bilinguals of higher proficiency level (of L2) should show superior performance in executive function tasks that do not require language processing

In the cognitive literature, executive functions have been shown to be influenced by different types of experience, e.g., physical exercise (Churchill, Galvez, Colcombe, Swain, Kramer, & Greenough, 2002), aging (e.g., Bugaiska, Clarys, Jarry, Taconnat, Tapia, Vanneste, & Isingrini, 2007; Bunce & Macready, 2005), increased experience with a particular task set (Dowsett & Livesey, 2000) and bilingualism (e.g., Bialystok, Craik, & Ryan, 2006). The magnitude of the influence originating from experience was often related to the degree of experience accumulated; the influence may be positive in some cases, such as training, but negative in others, such as aging.

The experience of managing two languages has been shown to alter performance on nonverbal executive functions. Nevertheless, current evidence is limited to showing a categorical difference between those who have the experience of managing two languages (fluent, balanced bilinguals) and those who do not (monolinguals). Comparing bilinguals who reported using both languages on a daily basis and who had attained high levels of proficiency in both spoken languages based on self-reports did not allow determining which aspects of the bilingual experience generate benefits and costs in nonverbal and verbal executive functions. If it is the *quantity* of the experience that matters, i.e., differential amount of daily usage between the two languages for bilinguals, then a relationship between the magnitude of benefits or costs and usage of two languages should be expected. On the other hand, if the *quality* of the experience, i.e., proficiency of languages, matters more, then a relationship between proficiency level and cognitive costs or benefits should be observed. It is also possible that daily usage of both languages interacts with proficiency (Perani, Abutalebi, Paulesu, Brambati, Scifo, Cappa, & Fazio, 2003) to affect cognition interactively. Therefore, to isolate the specific bilingual experience that gives rise to the opposing forces (positive in nonverbal executive functions, negative in verbal tasks), it is essential to differentiate usage and proficiency in bilingualism and examine their unique and interacting influences on cognition.

Although there is ample evidence showing bilinguals performing better than monolinguals on tasks that require executive functions, often in conditions that involve conflict, there is also evidence showing bilinguals outperforming monolinguals in conditions that contain facilitating (or non-conflicting) information. In the Simon task (Bialystok, Craik, et al., 2004; Martin-Rhee & Bialystok, 2008), bilinguals of different ages were observed to be better in both congruent and incongruent trials, leading to the speculation that bilinguals are better at picking up facilitating information as well as resisting distraction. In this case, bilinguals are not *only* better at inhibition, but also at selectively attending to peripheral information that aids in making decisions.

Assessing the bilingual influence on selective attention using the Attentional Network Test (ANT, Fan et al., 2002), Costa et al. (2008) found that bilingual university students were better than monolingual peers at alerting (picking up cue as to where the target will appear) and executive control (resolving conflict by ignoring the distracting flankers) but not orienting (directing attention according to a spatial cue). In the ANT, executive control relies on selective attention. The three attentional networks assessed in the ANT were found to be independent (Fan and Posner, 2004), i.e., uncorrelated with activation patterns of different neurological networks (Fan, McCandliss, Fossella, Flombaum & Posner, 2005) and response time performance (Fan et al., 2002). By using the ANT which embedded the three independent attentional constructs in the same task, Costa et al. (2008) used the paradigm to test different hypotheses within one experimental design. They found smaller interference effects in bilinguals, i.e., difference in reaction time between incongruent and congruent trials, which is analogous to Friedman and Miyake's (2004) construct of resistance to distraction and Norman and Shallice's (1986) willed control of attention. However, their bilinguals were faster in both congruent and incongruent trials. In this case, the interference effect simply reflects a difference between conflict resolution and facilitation because conflict resolution was involved in incongruent trials but facilitation was involved in congruent trials. The magnitude of conflict resolution and facilitation acquisition is still unknown. Regardless, there is evidence suggesting a bilingual advantage in managing attention, specifically in alerting and executive control.

In summary, evidence suggests that bilinguals are better in several subprocesses of executive functions: (1) inhibition and/or shifting (Miyake et al., 2000), specifically prepotent response inhibition and resistance to distraction; (2) SAS (Green, 1998; Norman & Shallice, 1986), managing attention at will; and (3) executive control and alerting network in the ANT (Fan et al., 2002). All these executive functioning mechanisms are implicated in psycholinguistic models of bilingualism, especially Green's ICM (1998). The role of skill level is also discussed in the context of SAS (Norman & Shallice, 1986), which was examined in terms of bilingualism in Kroll and Stewart's RHM (1994). In light of these parallel processes in bilingualism from psycholinguistic and cognition literature, advances in neuroimaging may help these fields converge on the architectural hardware of human cognition: the brain.

Converging bilingual processing and executive functions

The connection between language processing and a general control mechanism has been examined in light of neurocognitive literature on Broca's area (Homae, Hashimoto, Nakajima, Miyashita & Sakai, 2002; Novick, Trueswell & Thompson-Schill, 2005). Broca's area has traditionally been considered to be the language production centre, but this research suggests that it plays a more general rather than a linguistically restricted role in sentence processing and may provide executive control mechanisms in addition to language production (Novick, Trueswell & Thompson-Schill, 2005). In 1861, Broca discovered that the articulatory function is controlled by the third convolution of the inferior frontal gyrus by studying his patient, Lelong (*a.k.a.* Tan, Farah & Feinberg, 2000). Ever since then, the difficulty to produce fluent speech has been attributed to lesion or damage to Broca's area. Recent neuroimaging findings (Dronkers, Plaisant, Iba-Zizen, & Cabanis, 2007) suggest that Lelong may have had a lesion in an area that is anatomically much bigger than the focal area that Broca had considered as the language production area. Moreover, the specific location of Broca's area varies greatly across studies, leading to over-generalized attribution of behaviour to the general area of the left inferior frontal gyrus, which is conveniently called Broca's area. Even simple behaviour requires coordination and cooperation of different brain areas, e.g. finger-tapping activates both contralateral sensorimotor cortex, subcortical areas and ipsilateral cerebellum (Allison, Meador, Loring, Figueroa & Wright, 2000). Moreover, the plasticity of the human brain results in structural and functional changes in neuronal organization as a function of experience (Rosenzweig & Bennett, 1996).

Bilingual experience, being systematic and sustained behaviour, could result in functional and/or structural neurological changes. These changes are expected to influence a network of brain circuitry instead of a single brain area because language processing involves a network, not just a focal area (Binder, Frost, Hammeke, et al, 1997). Abutalebi and Green (2007) proposed a neurological network involved in bilingual processing. This network includes the prefrontal cortex, anterior cingulate cortex, inferior parietal lobule and basal ganglia, all of which are left-lateralized and are reported to be a network subserving executive functions (Carpenter, Just, & Reichle, 2000). This neurological connection is expected to shed light on how language experience affects cognition via its neurological effects enabled by brain plasticity.

Abutalebi and Green's (2007) neurological network adopted Bialystok's (1993) distinction between analysis and control. According to Bialystok (1993), the bilingual advantage should be evident in control but not in analysis because control concerns management of two language systems in bilingual activities (e.g., inhibition of the unwanted language), while analysis concerns representation of languages (e.g., lexicon of languages). Bilinguals need to represent two lexicons, and thus separate cognitive resources to each language, so they are unlikely to achieve higher than monolinguals who have only one language to represent. On the other hand, bilinguals should reap cognitive benefits from managing two language networks, such as inhibiting the unwanted language and dealing with the conflict of the simultaneous activation of two languages for a single concept. Therefore, the management of two languages, instead of the mental representation of two languages, recruits the coordination of Abutalebi and Green's network.

Abutalebi and Green (2007) distinguished contributions of the four areas in the left hemisphere that comprised their bilingual cognitive control network as follows. In the frontal lobe, the prefrontal cortex and the anterior cingulate cortex (ACC) both contribute to cognitive processes such as executive functions, decision-making, attention and conflict monitoring (e.g., Barbas & Zikopoulos, 2007; Botvinick, Cohen & Carter, 2004; Fassbender et al., 2004; Jonides, Lacey, & Nee, 2005; Stuss, 2006). The prefrontal cortex (including the ACC in this review), considered the seat of cognitive control, has three important properties: (1) convergence of diverse information from other parts of the brain; (2) plasticity; (3) feedback information to other brain areas (Miller & Cohen, 2001). According to these properties, the prefrontal cortex is involved in bottom-up processes to gather information from sensory areas of the brain, make decisions based on the input information and engage in feeding back (top-down) information to corresponding brain areas for execution of action. Of particular interest is the prefrontal cortex's plasticity property, which refers to flexibility or adaptability to rules. Miller and Cohen (2001) suggested that the prefrontal cortex biases the neurological network of executive functions towards a target rule representation relative to other competing rule representations, by controlling neuronal activity in other brain areas that targets that rule representation.

Controlling two languages may fit into Abutalebi and Green's (2007) framework of cognitive control. Rodriguez-Fornells, Rotte, Heinze, Nösselt & Münte (2002) found that highly proficient bilinguals had increased activation in the prefrontal cortex (Brodmann's Areas, BAs 45/9) when deciding to make a response to either Spanish or Catalan words. The authors speculated that activation in the prefrontal cortex is a consequence of inhibiting responses to the unwanted language and should activate when there was a need to choose to respond between languages. Similar patterns were found in highly proficient bilinguals when asked to name pictures, in which their non-language-specific brain areas (left middle prefrontal cortex) were recruited to control attention when faced with interference (Rodriguez-Fornells, van der Lugt, Rotte, Britti, Heinze, & Münte, 2005). The same authors also found recruitment of neurological areas known to be related to control of attention in bilinguals when they were asked to solve a nonverbal executive functioning task. Measuring neuronal activity in a magneto-encephalography (MEG) when conducting the nonverbal Simon task using squares as stimuli, Bialystok, Craik, Grady, Chau, Ishii, Gunji, and Pantev (2005) found that faster response time significantly correlated with prefrontal cortex activation and deactivation in highly proficient bilinguals, but not in monolinguals. In summary, the prefrontal cortex including the ACC is recruited in a range of executive processes and this recruitment differs between bilinguals and monolinguals in ways suggesting the influence of bilingual experience in the neural network responsible for controlling attention in the face of interference.

In Abutalebi and Green's (2007) model, subcortical areas were also involved in bilingual processing, mainly responsible for language selection and switching. The basal ganglia is responsible for motor control but also for learning and memory processes

(Packard & Knowlton, 2002), switching flexibly between sets of rules (for rat model[1], see Block, Dhanji, Thompson-Tardif & Floresco, 2007; Ragozzino, 2007; for human model, see Cools, Ivry & D'Esposito, 2006; Shafritz, Kartheiser & Belger, 2005) and handling automatic behaviour (Saling & Phillips, 2007). According to Miller and Cohen (2001), the prefrontal cortex is structurally connected to the basal ganglia. This is confirmed by diffusion-tensor imaging (DTI) studies (Aron, Behrens, Smith, et al., 2007) and fMRI studies suggesting a fronto-basal ganglia functional connectivity network (Aron, Durston, Eagle, et al., 2007; McNab & Klingberg, 2008). Although there is limited research examining the bilingual influence in subcortical brain areas, Crinion, Turner, Grogan et al. (2006) found that the left caudate of the basal ganglia was involved in language-universal control processes. Since subjects included German-English and Japanese-English bilinguals and activation in the left caudate was significant in both bilingual groups, it was also possible that the divergence in orthography points to an orthography-universal language switching similar to a language-universal switching (or lexical selection in Abutalebi & Green's [2007] terminology) behaviour. The left caudate has also been found to be activated in bilinguals when told to respond in only one language (Klein, Zatorre, Milner, Meyer, & Evans, 1994; Wartenburger, Heekeren, Abutalebi, Cappa, Villringer & Perani, 2003). From the neuroimaging evidence, Abutalebi and Green (2007) concluded that managing two languages did not only involve cortical areas, but also subcortical areas that were related to general cognitive control.

[1] Due to the technical difficulty in examining human subcortical structures, there is relatively more evidence in rat models than in human models. Therefore, both animal and human models are reported here.

The last landmark in the bilingual control network proposed in Abutalebi and Green (2007) is the left inferior parietal lobule. The major behaviour that recruits the left inferior parietal lobule is motor attention and selection (Rushworth, Johansen-Berg, Göbel & Devlin, 2003; Rushworth, Krams & Passingham, 2001). In a few neuroimaging studies that investigated bilingual processing between two languages, prefrontal activation was often accompanied by left inferior parietal activation in tasks that require language selection (Suh, Yoon, Lee, Chung, Cho & Park, 2007; Venkatraman, Siong, Chee & Ansari, 2006). In an influential study conducted by Mechelli and colleagues (2004), bilinguals' grey matter density in the left inferior parietal lobe (BA 40) was significantly correlated with their proficiency level in their L2 (English) and their age of acquisition of L2. Age of acquisition and proficiency are interacting factors in bilingualism. The earlier a second language is acquired, the higher proficiency level in L2 is attained (Hakuta, Bialystok, & Wiley, 2003). Therefore, it is quite difficult to differentiate age of L2 acquisition from L2 proficiency. In other words, it is uncertain whether changes in grey matter density in the left inferior parietal lobe are due to greater usage (in years) because of handling two languages or higher L2 proficiency. Nevertheless, findings from Mechelli et al., (2004) successfully showed structural changes in the brain related to bilingual experience.

Overall, neuroimaging studies that recruited bilinguals with different bilingual experience have shown that the neurological landmarks identified in Abutalebi and Green's (2007) bilinguals are related to bilingual processing. These landmarks have also been shown to be responsible for different cognitive processes, namely language-general executive functions. The ability to successfully manage two languages could be influenced by different characteristics of bilinguals, such as asymmetrical proficiency in L1 and L2 (Chee, Hon, Lee & Soon, 2001) or age of acquisition (Perani et al., 1998; Wartenburger et al., 2003). Essentially, there are many dimensions in bilingualism that need to be isolated and examined for their specific influence on language and cognition.

The Present Dissertation

The observed bilingual advantage in executive functioning tasks may suggest that an enhanced general control mechanism results from increased use of handling two language systems. The advantage appears only in tasks that required the greatest demand of control of attention (e.g., Bialystok & Senman, 2001; Bialystok & Shapero, 2005; Bialystok, Craik, et al., 2004; Martin-Rhee & Bialystok, 2008), but not in tasks that required access to linguistic representations (e.g., Gollan, Montoya, & Werner, 2002; Gollan & Silverberg, 2001; Ivanova & Costa, 2008). At the cognitive level, bilinguals have more practice over monolinguals in controlling attention to one of the two language systems. Therefore, this bilingual advantage could depend on *how much practice* (or usage) an individual has with attentional management, not necessarily on how proficient one is in a language. In this case, it is the usage of two languages that gives rise to this control mechanism.

This hypothesis, however, only concerns one dimension of bilingualism, practice. In the psycholinguistic literature, subjects were usually highly proficient bilinguals who were fluent in both languages. The term "fluent" in previous literature implies bilinguals who use two languages frequently and have attained a high level of proficiency (usually self-reported) in both languages. Since amount of practice and degree of proficiency are often confounded, it is possible that these two factors interact. The present dissertation examines the bilingual influence on executive functions in two steps: (1) isolate amount of practice and degree of proficiency that are proposed to be partial composition of bilingual experience; and (2) investigate the influence of these bilingual dimensions in verbal tasks and nonverbal executive function tasks.

Chapter 2 aims to achieve (1) by means of exploratory factor analysis. Young adults with a wide range of bilingual experience were given a questionnaire that assessed demographics, language usage and language history, standardized tests of proficiency in English (the language used to administer tests) and a battery of verbal and nonverbal executive functions tasks. The two major factors extracted were labeled as functional use of English and proficiency of English. Using the factor scores from functional use of English and proficiency of English, four subject categories were devised to differentiate levels of functional use of English and English proficiency. In study 2, bilingual participants were assigned to one of these four categories. Their performance in the verbal and nonverbal executive functions tasks were compared against each other and a monolingual sample.

From the cognitive perspective, it was hypothesized that levels of use would be related to bilingual individuals' enhanced performance on executive functioning tasks that require control of attention. From the linguistic perspective, bilingual individuals' proficiency level in one language was expected to be related to tasks that require specific knowledge of that particular language. As shown in the psycholinguistic literature, level of knowledge in L2 is related to semantic processing (Kotz & Elston-Guttler, 2004; Kroll & Stewart, 1994; Wartenburger et al., 2003) and lexical retrieval for picture naming (McElree, Jia & Litvak, 2000). These tasks require naming pictures in either language that a bilingual speaks. Therefore, it is expected that proficiency level in one language is related to the ability to use this language, but not directly to the bilingual advantage observed in performing nonverbal executive functioning tasks. However, both functional use of the two languages and proficiency (especially for L2) are expected to be related because increased usage usually leads to higher language proficiency. Therefore, the source of the bilingual advantage in nonverbal executive functions is hypothesized to be a consequence of the interaction between language proficiency and functional use of two languages.

The present dissertation aims to isolate the specific nature of elements that are responsible for the bilingual influence observed in verbal and nonverbal executive functions. From the cognitive and psycholinguistic approaches, it is hypothesized that degree of functional use in two languages exerts control over the two language systems productively and has a positive relationship with nonverbal executive functioning performance that demands high levels of cognitive control. However, this relationship is also influenced by a bilingual's language proficiency level because language usage and language proficiency are related (Cummins, 1991). In other words, the bilingual advantage in nonverbal executive functioning is expected to be dependent on the amount of practice (functional usage) in controlling two language systems and proficiency of at least one of the two spoken languages; while performance in verbal tasks is expected to vary primarily as a function of language proficiency, and secondarily as a function of usage. The differential roles of functional usage and proficiency of language are expected to be the sources of the bilingual advantage in nonverbal executive functions and the mixed performance in verbal tasks. Overall, this dissertation directly addresses the influence of an everyday experience of being a bilingual on higher level cognition. In addition, the implication of this influence will be extended to the neurological level and provide insights on the degree of cognitive plasticity in response to different linguistic experience.

The present dissertation sets out to examine the inconsistent findings in verbal and nonverbal task reported in bilingual research. In chapter 2, theoretical dimensions of bilingualism found in the literature, amount of balanced usage and language proficiency, were examined empirically via questionnaires. After establishing these dimensions mathematically and theoretically, a large sample of bilingual participants was categorized into subgroups according to high and low levels on these dimensions. In chapter 3, performance on verbal and nonverbal tasks was compared across one of the bilingual groups and monolingual group. The bilingual group chosen had the most contrasting language usage experience compared to monolinguals but also matched them on language proficiency. In chapter 4, comparisons were conducted across all bilingual subgroups and the monolingual group. The two dimensions of bilingualism are proposed to have different consequences on verbal and nonverbal task performance. Overall, this dissertation directly addresses the influence of an everyday experience of being a bilingual on higher level cognition.

Chapter 2. In search of balanced usage and language proficiency

Psycholinguistic studies comparing the performance of bilinguals and their monolingual peers suffer several methodological problems. Bilinguals' proficiency level in both spoken languages is often self-rated, sometimes in terms of usage, sometimes in terms of levels of proficiency (e.g., Elston-Güttler, Paulmann & Kotz, 2005; Gollan & Acenas, 2004; Gollan & Silverberg, 2001). In some cases, the "monolinguals" in these studies reported knowing more than one language, although their self-rated proficiency in this other language was significantly lower (Gollan, Montoya, & Werner, 2002). Some studies have reported bilinguals' usage of two languages but the measurement usually had limited variability (e.g., Chee, Soon, Lee & Pallier, 2004). Since bilinguals' balanced usage of languages was not the focus of these studies, the bilingual participants often had similar bilingual experience, such as high amount of balanced usage between languages and high self-rated proficiency of both languages. The consequence is that measurements for usage and proficiency did not vary sufficiently to assess whether performance varies as a function of these bilingual experiences. Conclusions from previous studies often attributed monolingual-bilingual group differences (advantage in nonverbal tasks, disadvantage in language tasks) to "bilingualism". However, it is puzzling how a single construct, namely bilingualism, can account for these divergent findings. Therefore, it is necessary to examine the influence of specific bilingual experience on language and cognition.

From the literature review, it is apparent that bilingualism is a dynamic construct that is composed of multiple dimensions. Most of the bilingual experiences in the literature have been reported qualitatively rather than quantitatively. In order to study the relationship between bilingual experiences, language and cognition, it is essential to assess empirically the theoretical dimensions derived from the psycholinguistic and cognitive literature review of bilingualism. Cognitive research has focused on the effect of experience on executive functions while psycholinguistic models of bilingualism have emphasized proficiency levels in the two languages and how the language systems interact. The present chapter describes a study that examined the nature of bilingualism and identified the dimensions of bilingual experience involved in the consequences of bilingualism. Participants were young adults who reported that they used more than one language on a daily basis, regardless of their relative proficiency in the languages and the amount of usage of each language. The inclusion of an unselected group of bilinguals in the present study was to increase the variability in bilingual experience to allow an investigation of the diversity of the construct.

Although the notion that bilingualism is not a categorical variable has been raised before (Bialystok & Hakuta, 1994; Hakuta, Bialystok & Wiley, 2003), surprisingly little research has been done on distinguishing the dimensions within bilingualism quantitatively. Typically, language acquisition history and daily usage are assessed through questionnaires. As Li, Sepanski and Zhao (2006) claimed, different laboratories use questionnaires that have unique aspects, although the majority of the questions overlap across questionnaires. The diversity of components included in these questionnaires indicates the complexity of bilingualism. Li, Sepanski and Zhao (2006) collected information from 41 published questionnaires and devised an online questionnaire that incorporates all their common questions. The major groups of questions included self-assessment of L1/L2, bilingual history (age of L2 acquisition, years of residence in the country where L2 is spoken), and home language environment.

In psycholinguistic research, bilinguals' relative proficiency in both languages was often self-rated and therefore prone to subjective bias. One possible way to improve the validity of self-rated proficiency is to measure respondents' formal L2 proficiency and see if their performance deviates from their self- report. Only L2 proficiency is suggested to be measured because L1 proficiency is assumed to be high and without much variability. However, the distinction between L1 and L2 does not necessarily reflect the dominant usage of each language or proficiency in each language (Flege, MacKay, & Piske, 2002). While L1 could be the language that was acquired first in a bilingual's life, it may not be the language that a bilingual uses on a daily basis. For example, many Canadian families speak heritage languages at home but English in the community. Children growing up in these families usually acquire the heritage languages first, which become their L1. Subsequently when these children receive formal schooling and use English to communicate with other children, English may become the dominant language in terms of usage. In this case, these children's L1s may not be the same as their dominant language, i.e., English, and that their L1 competence may diverge from native speakers of their L1.

Bilingualism is part of life experience, similar to any kind of experience, so it is not easy to study scientifically and systematically. However, it is possible to examine specific aspects of bilingualism that differ from monolingualism and have previously been shown to correlate with bilinguals' performance. In psycholinguistic research, bilinguals' proficiency level in both languages is the factor of most interest (e.g., Blumenfeld & Marian, 2007; Proverbio, Adorni, & Zani, 2007; Sumiya & Healy, 2008). However, bilingual experience does not affect only proficiency, i.e., how well one handles both languages, but also the amount of experience in handling two languages, i.e., how much usage or practice. For bilingualism, experience of using two languages can be examined in terms of age of acquisition or daily usage. Age of acquisition reflects the history of language acquisition, but may not represent the amount of daily usage. For instance, change of dominant language may not correlate with bilingual participants' age of acquisition (Flege, MacKay, & Piske, 2002). Therefore, in order to examine the effect of length of persistent practice in managing two language systems, the present study only considered average daily usage of both languages in the past five years. The five-year criterion was arbitrary because there was no literature examining the adequate length of prolonged practice on cognition. In fact, this would be highly influenced by individual differences. Based on the fact that the participants were all young adults attending university (around 20 years of age), the five-year criterion was used to provide a narrower window for their language usage behaviour that occupied about a quarter of their lifetime.

Existing instruments for assessing the nature or level of bilingualism are limited. Questionnaires seemed to be the most commonly used instruments. Marian, Blumenfeld and Kaushanskaya (2007) developed the Language Experience and Proficiency Questionnaire (LEAP-Q), validated it internally in 52 subjects (Study 1) and compared the self-rated proficiency responses reported to standardized measures of proficiency in 50 English-Spanish bilinguals (Study 2). The LEAP-Q required respondents to report, for each of their languages, age of acquisition, duration of stay in the current country of residence (United States), extent of language exposure and self-rated proficiency. Responses from the questionnaire were analyzed using factor analysis. In total, 16 factors with eigenvalues greater than 1 were retained. Eight of these 16 factors had an eigenvalue greater than 3 and accounted for 76% of the total variance. These three factors were L1 competence, Late L2 Learning and L2 competence.

Study 2 reported the relations between responses on LEAP-Q and standardized measures of proficiency. The general pattern of results confirmed the factors obtained in Study 1 and showed that self-rated proficiency from LEAP-Q correlated significantly with general behavioural measures of proficiency in English and Spanish. Eight factors were extracted from the Spanish-English bilinguals' responses. The first factor was labeled as "Relative L2-L1 competence" and it primarily consisted of variables measuring L1 or L2 exposure and degree of usage in the surrounding environment. The second factor was named "L1 learning" which included variables such as age of initial acquisition, age of attained fluency and self-perceived proficiency level of L1. The other factors were Late L2 Learning (which included variables such as length of L2 exposure), L1 nondominant status (included variables relating to L1 age of acquisition and exposure) and L2 Immersion (included variables measuring the length of L2 length of exposure in family and school). The objectives of the study are important and it has made a great contribution to understanding the dynamics of bilingualism. However, there are a few problems that limit the interpretation and the generalizability of the data.

First, the sample size (Ns = 52 and 50 in studies 1 and 2 respectively) was too small to conduct a factor analysis with 77 entries and 16 extracted factors. The resulting factors were deemed unstable (Hatcher, 1994; Comrey & Lee, 1992). Second, responses on the LEAP-Q were differentiated on a 5-point Likert scale. With variability this narrow, it is difficult to interpret results from multivariate analysis. Third, it was not clear whether the authors intended to conduct principal component analysis (PCA) or factor analysis. These analyses are not the same (Hatcher, 1994) but the authors appeared to use them interchangeably in the report. A PCA does not rely on underlying theoretical assumptions while factor analysis does. The analysis performed seemed to be a PCA, and not a factor analysis. Fourth, Study 2 recruited only Spanish-English bilinguals, which limited the generalizability of interpretations to all bilinguals (in Study 1, bilinguals speaking different languages in addition to English were recruited). Finally, the rotation method used in Study 1 does not allow factors to be correlated (varimax rotation). Factors in bilingualism are intertwined and not independent from each other (Bialystok, 2001). Therefore, the assumption of uncorrelated factors may result in factor loadings on the extracted factors that are unrealistically "clean". For instance, Marian, Blumenfeld and Kaushanskaya (2007) labeled the first three extracted factors as L1 competence, late L2 learning and L2 competence. These factors were derived using varimax rotation, a mathematical solution that maintains uncorrelated factors. It may be logical in mathematics, but in reality, late L2 learning and L2 competence can hardly be uncorrelated (Mechelli et al., 2004; Perani, Abutalebi, Paulesu et al., 2003).

The major improvements of the present study over previous studies included using a much larger and more heterogeneous bilingual sample, an oblique rotation (allowing factors to be correlated with each other), a continuous scale ranging from zero to ten instead of the 5-point Likert scale, and step-by-step exploratory and confirmatory factor analyses. These changes introduced more variance and more noise into the data, but also increased statistical power and validity significantly. These methodological changes were expected to increase the research power to identify dimensions embedded in bilingualism. Therefore, we could examine whether these bilingual experiences gave rise to the divergent results in bilingual research and the nature of the influence of these dimensions (or specific bilingual experience) on verbal and nonverbal tasks more directly than in past research.

Method

Participants

One hundred and sixty young adults between the ages of 18 and 30 years were recruited from York University, located in Toronto, Canada. All participants were undergraduates who participated for monetary reimbursement ($15) or course credit. Participation in the study was completely voluntary and no participant was excluded based on their language status. All testing was conducted in English.

All participants were roughly categorized as monolingual or bilingual based on their daily language experience. Participants who reported using two or more languages on a daily basis were categorized as bilingual. Other participants, who reported English as the only language they knew, were categorized as monolinguals. Three bilingual participants were excluded from the study because they reported knowing another language but did not use it on a daily basis. These participants could neither respond to questionnaires about their daily language usage nor be categorized as monolinguals. Without these three participants and according to the rough categorization, there were 117 bilingual participants (96 females, 21 males) and 40 monolinguals (30 females, 10 males). Although both language groups were predominantly female, the gender distribution was the same across the two groups, $\chi^2(1) < 1$, ns.

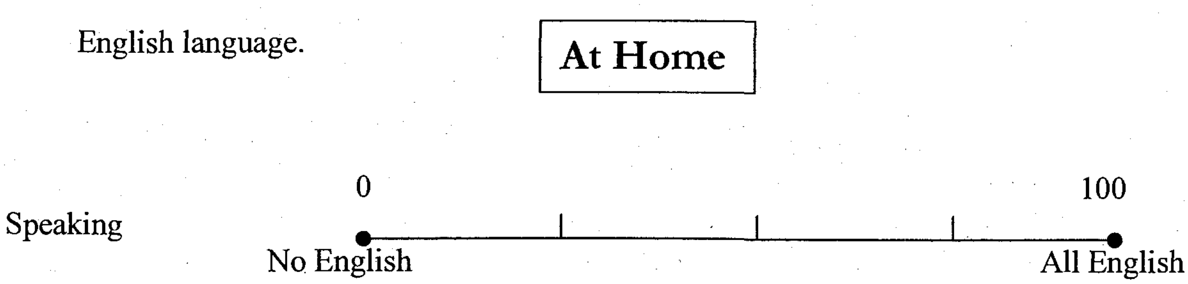
Materials and Stimuli

Language and Social Background Questionnaire (LSBQ). The LSBQ contains three main sections: (1) demographic information; (2) daily usage of languages and self-rated proficiency; and (3) life history of bilingualism (see Appendix A). Trained experimenters presented the questionnaire as a casual conversation and filled it out, instead of having participants complete the questionnaire independently, to avoid misinterpretation of the questions.

All participants were asked to fill out section (1), demographic information. This section included age, years of education, place of birth and age of arrival in Canada (if not born in Canada), and first and second languages spoken on a daily basis. First language, or L1, in this study, was interpreted as native language or the language to which participants were first exposed at home. In this case, L1 may not be the same as the participants' dominant language in terms of usage. For example, a participant could be exposed to a non-English language at home from birth, but mostly use English as a communicating language.

Sections (2) and (3) were only given to bilingual participants. Section (2) assessed participants' daily balance of usage between their L1 and L2 and self-ratings on L1 and L2 language proficiency. For balance of usage, participants were asked to rate the proportion of use of English and the non-English language on a 10 cm visual analog scale (VAS, see an example in Figure 1). VAS is commonly used to assess level of pain in the medical literature and is shown to be a simple measurement of ordinal preference (McCarthy, Chang, Pickard et al., 2005; Torrance, Feeny & Furlong, 2001). The left end indicates no English usage at all, and the right end indicates all English usage. Language activities, i.e., speaking, listening, reading and writing, were presented in four different scales. Participants were asked to judge their balance of language usage on these scales in the context of home and work. In addition, in the home context, they were also asked to judge the balance of usage in watching TV and listening to radio. A total of 10 scales relating to functional usage between two languages were presented.

Figure 1. A sample VAS assessing proportion of usage between the English and non-English language.



The first part of section (3) was similar to section (2). Participants were asked to rate their proficiency level for each of their L1 and L2 relative to native speakers on eight 10 cm VASs. Proficiency level relative to native speakers was used as less subjective than self-rated proficiency with no relative benchmark. Individual perception of proficiency level can vary considerably, so proficiency level relative to native speakers defined a common baseline. Self-rated language proficiency was assessed for speaking, listening, reading and writing. VAS responses in sections (2) and (3) were measured to one decimal place and recorded as ratio variables. These measurements were made after the testing session by two trained research assistants. The second part of section (3) in LSBQ concerns additional information regarding the participants' history of learning L2. Three ages of acquisition were assessed: age of L2 acquisition formally, age of L2 acquisition informally, and age of active bilingualism.

Peabody Picture Vocabulary Task-III, Form A (PPVT-III, Dunn & Dunn, 1997). PPVT-III was used to measure participants' receptive vocabulary level. The reported median Cronbach's alpha of PPVT-III is .95 (Dunn & Dunn, 1997). A page of four black-and-white line drawings were shown along with a word produced by the experimenter. Participants were asked to choose one of the four pictures that best described the word the experimenter said, either by saying the number of the picture or pointing to the picture. Items in PPVT-III were grouped in sets of 12 and arranged in increasing level of difficulty. Basal and ceiling sets were established for each participant based on the number of errors made in a set. A basal set was established when one or no error was made. A ceiling set was established when eight or more errors were made, at which point testing terminated. A raw score was obtained by subtracting the number of errors from the number of the last item in the ceiling set. Raw scores were transformed to standardized scores using an age-corrected norm table. Standardized scores were used in analyses.

Expressive Vocabulary Task (EVT, Williams, 1997). EVT was used to measure levels of expressive vocabulary in English. The reported median Cronbach's alpha of EVT is .95 (Williams, 1997). EVT was co-normed with PPVT-III. Participants were asked to provide a one-word synonym for a presented picture and a word given by the experimenter. Similar to the PPVT-III, items were arranged in increasing difficulty and basal and ceiling sets were established. Unlike PPVT-III, items were not grouped into sets. The basal set in EVT was the set of items with five or more consecutive correct answers. The ceiling set was the set of items on which participants made five or more consecutive errors. On the response sheet, two columns of correct and incorrect responses were presented. To keep testing sessions within reasonable time limits, EVT administration in this study did not include prompting correct responses even though standardized clinical administration allows it. Clinical application of the EVT aims at maximizing the potential of respondents, so prompting is a strategy to elicit correct responses. This aim did not apply to this study because participants were from a typical population of young adults. Furthermore, EVT was included in this study to provide an objective measure of expressive vocabulary level in English, which required all participants to be given the same administration. This modification of standardized administration was then justified. Calculation of raw and standardized scores was similar to that of PPVT-III. Age-corrected standardized scores were used in analyses.

Procedures

Informed consent (Appendix B) was obtained from all participants prior to the beginning of the testing session. Participants then completed the LSBQ, PPVT-III and EVT plus a battery of tasks. Only LSBQ, PPVT-III and EVT were relevant to the present experiment; the other tasks were relevant to other analyses, and are explained in Chapter 3. LSBQ was administered at the beginning of the testing session. PPVT-III and EVT were presented towards the end of the testing session, interrupted by a computer task.

Data Analysis

All data analyses were conducted using Statistical Analysis System (SAS) version 9.1.3. Responses on the LSBQ and standardized scores from PPVT-III and EVT were first examined with exploratory factor analysis (EFA), then evaluated with confirmatory factor analysis (CFA). Throughout the analysis, EFA and CFA were alternated. This was suggested as good practice because observed factor structures and theoretical latent factors may not be compatible (Browne, 2001). Therefore, in order to achieve a valid model, researchers should learn more about the data structures from EFA, then evaluate the model fitness of CFA before returning to run another EFA with refined data. The major reason for using factor analysis (FA) rather than principal components analysis (PCA) is that the question of interest was whether specific bilingual experiences (functional usage from cognition research, language proficiency from psycholinguistic research) map onto opposing forces (advantage in cognitive control, disadvantage in language proficiency). With these preconceptions developed prior to analyzing the data, FA can be used to confirm the existence of these specific bilingual experiences and to examine their nature and relationship. On the other hand, PCA only provides linear combinations of variables that maximize variances in the data. In other words, interpretation and execution of FA aims at confirming (or rejecting) latent constructs in observed variables while PCA only provides a mathematical combination that captures the most variance in the data. Moreover, PCA takes into account total variance while FA ignores unique and error variances (Tabachnik & Fidell, 2007). In other words, PCA focuses on variances between variables but FA focuses on covariances between factors and variables.

Despite the large sample size (117 bilinguals), not all questionnaire items were entered into the analysis. For instance, demographics and bilingual history variables were not included in the factor extraction. This was to ensure the sample to factor ratio to be as efficient as possible (Hatcher, 1994). Two model construction criteria were determined a priori that fit the research question: extraction method and rotation method. Since the initial analysis was exploratory in nature, several models were conducted and each one was evaluated for model efficiency, theoretical adequacy and number of factors extracted. The extraction method chosen was maximum likelihood (ML) with Heywood adjustment. ML extraction was used because the analysis provides significance tests allowing the researcher to determine if the number of extracted factors is sufficient to explain covariances between variables. Also, ML extraction estimates factor loadings by maximizing the likelihood of sampling the observed correlation matrix in the population.

Oblique rotation was chosen to allow correlation between factors. The SAS promax method was used instead of other available oblique rotation methods because it is fast and does not require a large amount of data.

The labeling of extracted factors was determined by the experimenter. The number of factors retained was evaluated by four criteria: (1) Eigenvalues of extracted factors; (2) scree plot; (3) significance tests from ML extraction; and (4) suitability of factor loadings. As an additional guideline, the goal of Study 2 (comparing performance of subgroups of bilinguals) was maintained in order to devise two theoretically dependent dimensions but maximize their uniqueness. The major goals of the analysis are to identify the number of valid factors embedded in bilingualism based on data collected from the present LSBQ and to confirm the existence of the theoretical dimensions, namely amount of usage in both languages and proficiency of English (which could be participants' L1 or L2).

Data screening and pre-processing

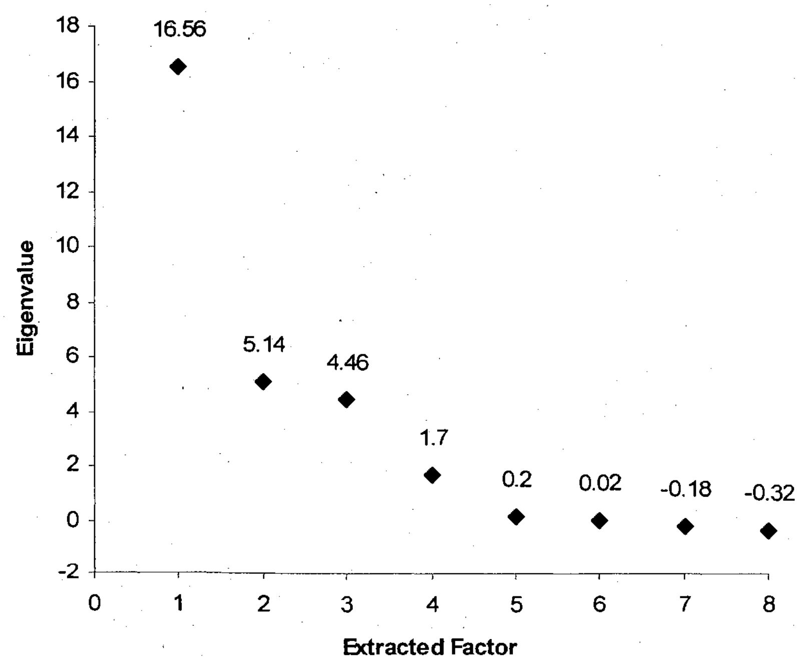
According to Tabachnik and Fidell (2007), multivariate outliers may significantly decrease the fit for multivariate models in exploratory data analysis. Multivariate outliers are observations that scatter at the extremes of the multivariate distribution of the whole sample when variables of interest are considered. The distance of each observation from the "grand mean" (centroid) of all variables considered is called the Mahalanobis distance. A macro (%outlier, Friendly, 2003) generated in SAS was used to calculate the Mahalanobis distance for each observation in the dataset, taking into account interrelationships between the variables of interest in the factor analysis: home usage of speaking and listening (0 = no English at all, 100 = all English), self-rated English and non-English proficiency in speaking and comprehension (0 = non-native-like, 100 = native-like) and formal English proficiency (PPVT-III and EVT). Results generated from the %outlier macro identified fifteen observations (about 12.8% of the 117 bilingual observations) as potential multivariate outliers. Using cutoff criteria of 25 and $\alpha = .001$ for the robust squared distance and p-value for chi square trimming (based on suggested critera given in the %outlier macro), eight of the 15 observations were valid multivariate outliers and were therefore excluded from further analysis. Five bilingual participants' EVT performance was not recorded due to experimenter error. Therefore, 104 bilingual observations were included in the initial exploratory factor analysis.

Violation of univariate assumptions such as linearity, normality and homogeneity of variance may also affect multivariate analysis. Nonetheless, exploratory factor analysis is fairly robust to minor violations of univariate assumptions. Self-rated non-English proficiency, home language usage and formal English proficiency variables were marginally fit for these univariate assumptions, but not self-rated English proficiency. The distributions for speaking and listening of English proficiency were highly negatively skewed (skewness = -2.04 and -1.29 respectively). When evaluating the rotated factor patterns, extracted factors on which the self-rated English proficiency variables loaded were carefully reviewed because of their possible skewness.

Results

Comparisons of models. Exploratory factor analysis extracted four factors with eigenvalues greater than one (an eigenvalue greater than one signifies that a factor contributes more than one unit of variance in the data). Hatcher (1994) suggested that only factors with eigenvalues greater than one should be retained in the model. Therefore, based on this criterion, four factors were retained. The second evaluating criterion was the scree plot, a visual representation of the extracted factors' eigenvalues (see Figure 2). The objective was to look for a "break" in the continuum of values, which serves as a basis for identifying the number of meaningful extracted factor(s). The scree plot helps to identify the number of retainable factors in the analysis. In this case, a "break" between successive data points would indicate the number of factors to be retained.

Figure 2. Scree plot from exploratory factor analysis indicating three "breaks".



Visual inspection of the scree plot indicates a first break between factors 1 and 2, a second between factors 3 and 4, and a third between factors 4 and 5. With three breaks in the scree plot, the adequate number of factors to extract from the data is indeterminate.

The positions of the three breaks suggest three possible solutions: one-factor, three-factor and four-factor. The one-factor solution is inconsistent with the proposed research questions and the theoretical nature of bilingualism, so it was not pursued in subsequent analysis. Both three- and four-factor solutions fit the theoretical nature of bilingualism. The eigenvalue of one criterion indicates that four factors should be retained, which is consistent with one of the solutions suggested by the scree plot. Based on the eigenvalue of one criterion and the scree plot, both three- and four-factor models were investigated further.

Significance tests obtained from the ML extraction were used to confirm the adequacy of the three- and four-factor exploratory models and were treated as a confirmatory strategy. Chi-square tests for model fitting were used for this purpose. A significant result indicated that the model with specified number of extracted factors being tested was not sufficient to explain the complete set of data. Therefore, the goal of these tests was to reach an insignificant chi-square test. The first significance test examined if the model structure suggested more than one common factor extracted from the complete dataset and confirmed the hypothesis, χ^2 (28) = 429.84, $p < .0001$. The next tests examined whether a three-factor model was sufficient to explain the eight variables, and the results indicated that a three-factor model was insufficient, χ^2 (7) = 49.32, $p < .0001$. Finally, the same tests confirmed that the four-factor solution was sufficient to explain the multivariate relationship of the variables, χ^2 (2) = 2.67, *ns*. On this basis, the four-factor solution appeared to be the most appropriate solution to the model.

Table 1. Factor loadings and estimated communalities (h^2), and percents of variance and covariance for maximum likelihood extraction and promax rotation on the LSBQ data[a].

Variable	**F1**[b]	**F2**	**F3**	**F4**	h^2
Home usage of speaking English	.11	**.91**	.10	.02	.85
Home usage of listening to English	.07	**.84**	.11	.00	.72
Self-rated level of speaking English	**1.00**[c]	.01	.05	.07	1.00[d]
Self-rated level of understanding English	**.79**	.00	.04	.08	.63
Self-rated level of speaking non-English	.03	.07	.19	**.63**	.44
Self-rated level of understanding non-English	.00	.03	.04	**1.03**	1.06
Receptive English vocabulary (PPVT-III)	.05	.03	**.79**	.02	.63
Expressive English vocabulary (EVT)	.04	.07	**.87**	.05	.77
Proportion of variance accounted for	.41	.39	.36	.37	
Proportion of covariance accounted for	.27	.25	.24	.24	

[a] Table entries are obtained from rotated factor pattern.
[b] Suggested factor labels: F1 = Self-rated proficiency of oral English; F2 =Home usage of two languages; F3 = Formal English vocabulary level; F4 = Self-rated level of oral non-English language.
[c] bold cell values highlight factor loadings above 0.45.
[d] estimated communalities equal or exceed 1 because (1) of the oblique rotation; and (2) possible problems with the solution.

Factor loadings, estimated communalities, and proportion of variance and covariance from the ML extraction are reported in Table 1. Tabachnik and Fidell (2007) suggested considering only factor loadings greater than 0.45 (20% of variance) as significant. Visual inspection of factor loadings indicated that each variable loaded on only one of the four extracted factors after promax rotation. All four factors extracted had an eigenvalue greater than one. From visual inspection of the pattern matrix reported in Table 1, it was clear that variables measuring self-rated proficiency level of oral English and the non-English language formed factors 1 and 4. Factors 2 and 3 were involved with use of two languages and self-rated proficiency of English. The labeling of factors 1, 3 and 4 was fairly transparent because variables loading on these factors were of ratio scale. However, the labeling of factor 2 required some explanation. The two variables loading on factor 2 were the visual analog scales measuring how "balanced" oral usage of speaking and listening to English and the other language was in home settings. English was depicted on one extreme of the scale, the non-English language at the extreme. Coupled with the overall highly biased usage of English in work settings, participants who used more non-English language at home indicate more "balanced" usage between languages, hence "balanced" bilingualism.

The four-factor solution provides a comprehensive account based on the one-eigenvalue criterion, the scree plot, and the significance tests from ML extraction. Its problem, however, is that it does not pass the model efficiency and internal consistency criteria. First, as reported in Table 1, a few a priori estimated communalities are greater than or equal to one. Communality estimates indicate, for each variable, the estimated proportion of variance shared with a common factor. Estimates greater than or equal to one suggest problems, such as too little data and/or too many factors extracted. Although these communality estimates contradict ML extraction significance tests, they were interpreted as cautionary because they indicated that the model's internal consistency was not achieved. The problems were possibly caused by the non-normality of the self-rated proficiency variables. Second, the significant correlations between factors (see Table 2) indicate complex factor structures that reflect intercorrelations between factors, confirming the expectation that bilingual experiences were correlated, with the self-rated proficiency variable highly correlated with other factors. The goal of this factor analysis was to generate factor scores for bilingual subgroup comparisons; therefore, Tabachnik and Fidell's (2007) suggestion of using simple factor structures for ease of interpretation was adopted. The self-reported proficiency variables were eliminated because of their skewed distributions and high correlations with other factors.

Table 2. Correlations between factors extracted from the four-factor solution.

Factor	**F1**	**F2**	**F3**	**F4**
F1: Self-rated proficiency of oral English	--	-.45**	.28*	-.30*
F2: Home usage of two languages		--	.30*	.34*
F3: Formal English vocabulary level			--	.53**
F4: Self-rated level of oral non-English language.				--

* $p < .01$ ** $p < .001$

The Final Model. The model was improved in two ways: (1) eliminating self-rated proficiency measures; (2) using alpha factoring for extraction. The four self-rated proficiency variables (speaking and listening in English and non-English languages) were excluded because factors extracted from these variables were highly correlated with other factors to the extent that the latter contributed little uniqueness to the model. Therefore, the final model included four variables, home language usage in speaking and listening, PPVT-III, and EVT. Alpha factoring was used for extraction instead of ML to take advantage of the reliability (or generalizability) of the factors extracted. As with ML extraction, alpha factoring aims to maximize the probability of sampling the observed correlation matrix in a population. The difference is that in ML extraction, the population of sampling correlation matrices is of interest but in alpha factoring, the population of extracted factors is the focus. A major feature of alpha factoring is that it maximizes Cronbach's alpha for the common factors, i.e., it maximizes the reliabilities of the extracted factors. Oblique rotation was retained as the solution because it was more theoretically plausible to consider functional usage of English and proficiency of English related rather than as two independent constructs. The one-eignenvalue criterion, scree plot and factor loadings from an orthogonal rotation were used as evaluating criteria.

Before running a factor analysis for the final model, multivariate outliers were detected again using the %outlier macro including only the four variables. Including the original 112 bilingual observations and the same $\alpha = .001$ cutoff, two observations were identified as significantly deviating from the rest of the sample and were excluded in the final factor analysis. The one-eigenvalue criterion indicated that two factors should be retained. This decision was confirmed by inspecting the scree plot (see Figure 3). In Figure 3, the only break indicated was between factors 2 and 3. The alpha coefficients of the first two factors were 0.82 and 0.37 respectively. The interpretation of the alpha coefficients was similar to that of Cronbach's alpha. These coefficients were intended to signify the internal consistency of the variables loading onto each factor. Factor loadings of the four variables onto these two factors are shown in Table 3; the two language usage variables clearly load on the first factor and the English formal vocabulary variables on the second. Squared multiple correlations (SMCs) are calculated by treating each factor as dependent variable and all loading variables as predictors in a standardized regression. High SMCs indicate that the factors are well-predicted by the predictors, i.e., variables loading onto that factor. SMCs for factors 1 and 2 were 0.89 and 0.85 respectively, indicating internally consistent factors were obtained from the variables. Estimated communalities (h^2) are high and less than one, indicating that the variables are well-defined by these factors. Finally, the correlation between the factor 1 and factor 2 was moderate, $r = .35, p < .001$. With the two home usage of oral English loading onto the first factor, this factor was labeled as *bilingual usage*, in line with English being the predominant language used outside the home. The second factor had PPVT-III and EVT loaded on it, both of which measure formal proficiency of English vocabulary. Therefore, factor 2 was labeled as *English proficiency*.

Figure 3. Scree plot from the final model.

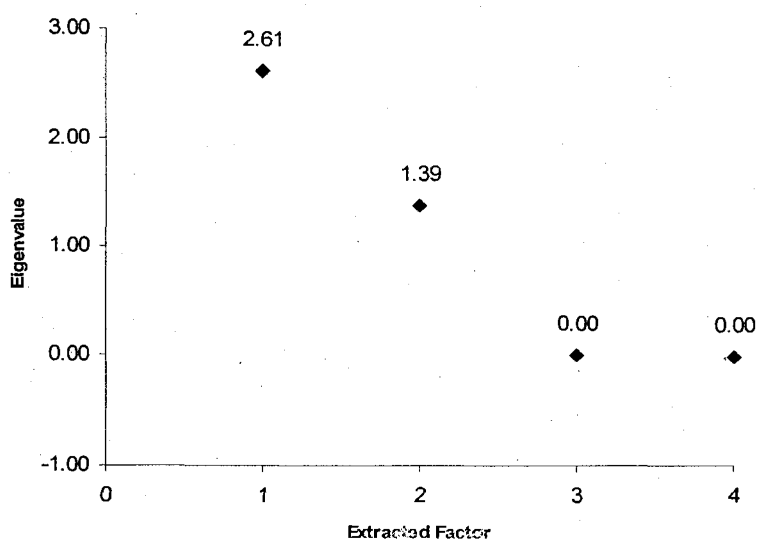


Table 3. Factor loadings, estimated communalities (h^2), and proportion of variance and covariance for alpha factoring extraction and promax rotation.

Variable	F1[a, b]	F2	h^2
Home usage of speaking English	**.86**	.14	.84
Home usage of listening to English	**.89**	.12	.74
Receptive English vocabulary (PPVT-III)	.06	**.86**	.77
Expressive English vocabulary (EVT)	.06	**.85**	.70
Proportion of variance accounted for	.77	.75	
Proportion of covariance accounted for	.51	.49	

[a] Factor labels: F1 = Functional use of oral English at home. F2 = Formal proficiency of English vocabulary.
[b] bold cell values highlight factor loadings above 0.45.

Profiling Bilinguals. Bilingual participants were categorized into different subgroups using factor scores obtained from the factor analysis. Factor scores are estimates of each individual subject on each factor if they were to be measured in that factor directly (Tabachnik & Fidell, 2007). In other words, the factor scores from the final model provide each bilingual participant's estimates for *bilingual usage* and *English proficiency*.

Each of the 110 bilingual participants was given two factor scores, one for *bilingual usage* and one for *English proficiency* (see scatterplot, Figure 4). Using the origin as the centroid of the scatterplot (intersection of grey lines, Figure 4), each factor was separated into two halves. Quadrants of the scatterplot then form four bilingual profiles differing in bilingual usage and English proficiency. Since some participants fell on cutoff lines, scores less than or equal to zero in either factor were placed in the lower level and those greater than zero in the higher level. There was a moderate but significant correlation between these two factors, $r = .35, p < .001$, so these quadrants generated unequal sample sizes.

Figure 4. Scatterplot of *bilingual usage* and *English proficiency* factor scores.

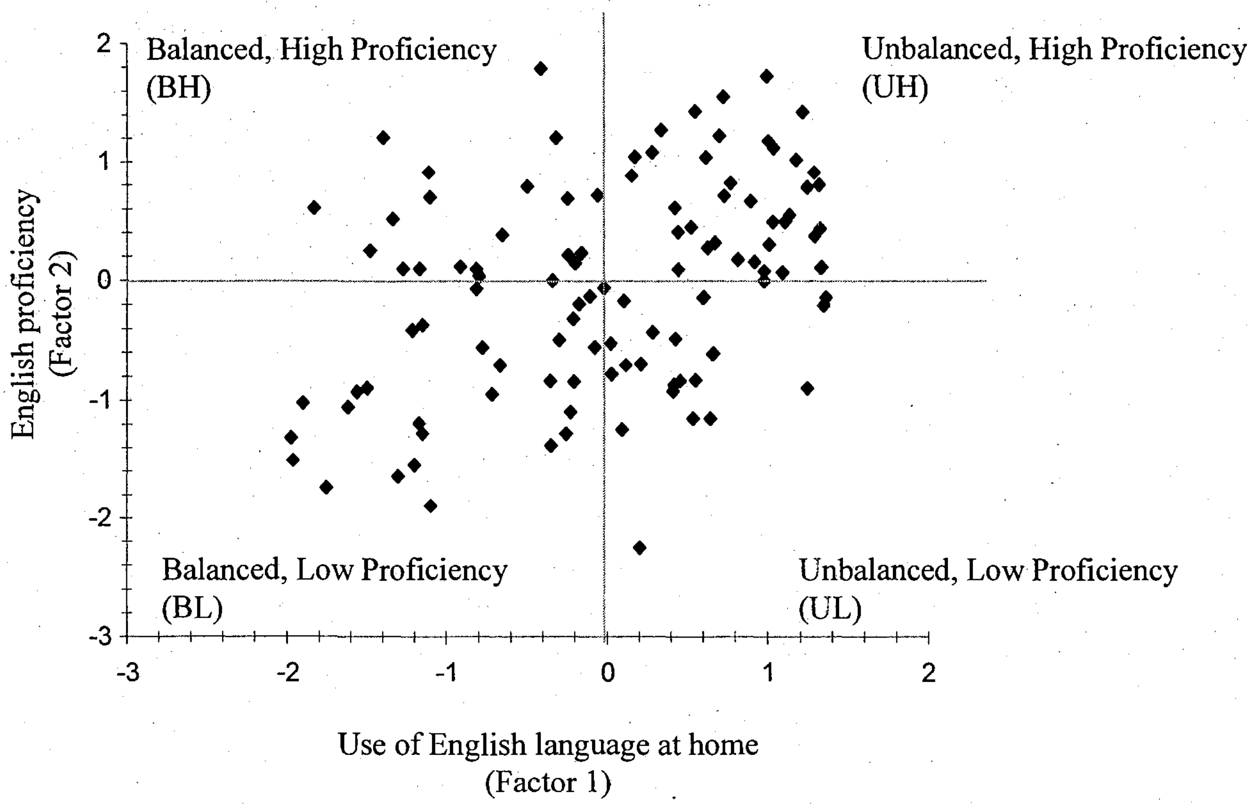


Figure 4 shows the four bilingual profiles generated. Bilinguals to the left of the vertical grey line were fairly balanced in handling their two languages (reportedly high non-English language usage at home). Bilinguals to the right of the vertical grey line were unbalanced in bilingual usage because they used English in both home and work settings. Bilinguals above the horizontal grey line scored high on English vocabulary assessments, while those below scored (relatively) lower. Quadrants form four subgroups of bilinguals differing in level of bilingual usage and English proficiency: (1) Balanced bilingual usage and High English proficiency (BH, n = 22); (2) Balanced bilingual usage and Low English proficiency (BL, n = 29); (3) Unbalanced bilingual usage and High English proficiency (UH, n = 38); and (4) Unbalanced bilingual usage and Low English proficiency (UL, n = 21). Hereafter, bilingual subgroups are represented by their two-letter abbreviations, and the monolingual group by a single letter (M, n = 40).

Bilingual Subgroup Characteristics. The four bilingual profiles differed on characteristics beyond the two defining factors. Ample information was obtained in the LSBQ, PPVT and EVT; items related to the present analysis were compared across the four bilingual and the monolingual subgroups. Four major clusters of characteristics were included in comparisons: (1) demographics; (2) post-hoc confirmation of bilingual usage and English vocabulary; (3) bilingual history; and (4) self-rated English and non-English proficiency.

First, the demographic characteristics of the subgroups were compared. Table 4 presents background demographic information on the bilingual and monolingual subgroups. Other than sample size, only the proportions of participants reporting English as L1 and being Canadian born differed significantly between subgroups. In both cases, the majority of participants in UH and M groups reported having English as the first language and being Canadian born. All of the 23% monolinguals who reported being non-Canadian born were born in another English-speaking country (e.g., England or the United States). Although 40% of the BH bilinguals reported being Canadian-born, only half of the 40% claimed English as their first language. Their responses indicated that a non-English language was spoken in the house and they were first exposed to the home language instead of English.

The number of daily video gamers was tested because of evidence that video game experience affects visual processing (Green & Bavelier, 2006, 2007) and speed of processing (Bialystok, 2006) and selective attention (Castel, Pratt, & Drummond, 2005). There was no significant difference in the distribution of daily video gamers across subgroups. Finally, the five subgroups did not differ in chronological age or years of education. In terms of demographics, bilingual and monolingual subgroups differed only on L1 status and place of birth.

The factor analysis provides a multivariate solution to examine the two dimensions embedded in bilingualism. As a post-hoc confirmation of the profiling dimensions obtained from the factor analysis, bilingual usage (LSBQ) and English vocabulary (PPVT, EVT) were compared across groups (see Table 5). This comparison did not only confirm the multivariate solution to the problem of identifying specific bilingual experiences, it also allows inspection of the between-group univariate

Table 4. Demographic characteristics of the bilingual subgroups and monolinguals.

Characteristic	**BH**[a]	**BL**	**UH**	**UL**	**M**	**Statistical test**[b]
Sample size	22	29	38	21	40	χ^2 (4) = 10.33, $p < .04$
Proportion of females	.72	.96	.78	.76	.75	χ^2 (4) = 6.53, *ns.*
Proportion of English as L1	.22	.14	.89	.47	1.00	χ^2 (4) = 81.54, $p < .0001$
Proportion of Canadian born	.40	.10	.71	.33	.77	χ^2 (4) = 40.06, $p < .0001$
Proportion of daily video gamers	.31	.10	.26	.09	.27	χ^2 (4) = 6.55, *ns.*
Age in years[c]	20.55 (1.57)	21.34 (2.44)	21.05 (2.04)	21.05 (2.06)	21.00 (1.84)	F (4, 145) < 1, *ns.*
Years of education[c]	14.57 (1.07)	14.45 (1.54)	15.00 (1.74)	14.81 (1.68)	14.84 (1.68)	F (4, 145) < 1, *ns.*

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.

[b] Proportions were compared using chi-square non-parametric tests of frequency data. Means were compared using one-way ANOVAs for unequal sample sizes.

[c] Shown are means, with standard deviations in parentheses.

distributions in the four variables that were used to derive the two dimensions. The bilingual subgroups differed significantly on both bilingual usage variables, *Fs* $(3, 106) > 4.0$, *ps* $< .01$. Contrasts were assessed by post-hoc Tukey's honestly significant difference (HSD) tests, to control for Type I error in multiple tests, using harmonic cell sizes to control for the unequal sample sizes. On reported bilingual usage of English at home (speaking), UH bilinguals were slightly higher than UL bilinguals and both balanced bilingual groups, $F(1, 106) > 3.7$, $p < .05$; the two balanced bilingual groups did not differ from each other, $F(1, 106) < 3.7$, *ns*. For listening usage of English at home, the balanced and unbalanced bilingual subgroups differed from each other, $F(1, 106) > 3.7$, $p < .05$, with no difference between high and low English vocabulary groups, $F(1, 106) < 3.7$, *ns*. Despite near ceiling values for bilinguals' usage data in the work setting, a similar pattern of results was found for speaking except that low English vocabulary groups did not differ from each other, $F(1, 106) < 3.7$, *ns*. Finally, no bilingual group differences were found in listening to English in the work setting.

For comparisons involving English formal vocabulary, the monolingual group was also included. Relative to the pattern suggested by HSD tests for bilingual usage variables, the pattern suggested by HSD tests for English vocabulary variables is more homogeneous. For both receptive (PPVT-III) and expressive (EVT) vocabulary, the high vocabulary bilingual group (BH and UH) differed from the low vocabulary bilingual group (BL and UL); the monolingual group was similar to the high vocabulary bilingual

Table 5. Bilingual usage and English vocabulary variables for the bilingual and monolingual groups.

Variables	BH[a]	BL	UH	UL	M	Statistical test
Bilingual usage at home						
Speak	3.72 (1.87)	3.06 (2.31)	8.96 (1.12)	7.19 (1.69)	--	$F\,(3, 106) = 78.73, p < .0001$
Listen	3.11 (2.09)	3.51 (2.14)	7.97 (1.47)	7.94 (1.44)	--	$F\,(3, 106) = 60.57, p < .0001$
Bilingual usage at work						
Speak	7.97 (2.30)	8.30 (2.27)	9.56 (0.92)	9.48 (0.85)	--	$F\,(3, 106) = 6.23, p < .001$
Listen	8.42 (2.29)	8.36 (2.17)	9.53 (1.08)	9.52 (0.81)	--	$F\,(3, 106) = 4.27, p < .01$
English formal vocabulary						
Receptive (PPVT-III)	104.73 (8.07)	85.66 (8.89)	106.32 (7.06)	87.38 (7.79)	102.79 (9.89)	$F\,(4, 144)^{b} = 39.21, p < .0001$
Expressive (EVT)	97.68 (12.58)	73.14 (8.44)	97.24 (11.56)	75.14 (10.67)	95.53 (12.55)	$F\,(4, 145) = 33.52, p < .0001$

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.
[b] One monolingual's PPVT data failed to be recorded due to experimenter's error.

group (BH and UH), *Fs*(4, 144) > 33.5, *ps* < .0001. Considering all bilinguals as a group, their performance in both receptive and expressive English vocabulary was significantly lower than monolinguals', *F*s (1, 144) > 18.11, *p*s < .0001; this finding is consistent with previous findings in young adults (Portocarrero, Burright & Donovick, 2007). These comparisons of bilingual usage and English formal vocabulary variables confirm the bilingual profiling dimensions from the factor analysis.

Following confirmation that the profiled subgroups reflect the expected characteristics, the bilingual subgroups' history of bilingualism was also compared (see Table 6). Age of L2 acquisition was examined from two perspectives: formally at school and informally at home. These two perspectives were included to assess whether mode of instruction in L2 acquisition affects bilingual usage and English vocabulary. Although not all bilingual participants reported that they acquired L2 formally and/or informally, one-way ANOVA models were conducted on those participants that did. There was no group difference in age of L2 acquisition either formally or informally, *F*s(3, 57) < 2.0, *ns*. Formal L2 acquisition typically started around six years old, when most bilingual participants started formal education. Ages of informal L2 acquisition were typically below the age of six, indicating initial acquisition of L2 at home. Age of active bilingualism was also assessed because language acquisition is a gradual process, and age of starting to acquire L2 does not necessarily indicate age of starting active usage of two languages on a daily basis. The bilingual subgroups differed in their age of active bilingualism, $F(3, 99) = 6.7, p < .0005$. Post-hoc Tukey HSD tests showed that the BL

Table 6. Means and standard deviations of bilingual history variables and self-rated proficiency for the bilingual subgroups.

Variables	BH[a]	BL	UH	UL	Statistical test
Bilingual history[b]					
Age of L2 acquisition formally at school	6.24 (3.32) n = 21	8.13 (3.44) n = 28	6.85 (3.11) n = 34	6.93 (3.58) n = 20	$F(3, 99) = 1.43$, *ns.*
Age of L2 acquisition informally at home	3.46 (3.04) n = 13	4.63 (3.03) n = 15	2.34 (4.43) n = 28	5.22 (3.83) n = 9	$F(3, 61) = 1.92$, *ns.*
Age of active bilingualism	8.11 (4.89) n = 22	13.34 (5.66) n = 29	7.50 (5.69) n = 34	10.78 (5.92) n = 18	$F(3, 99) = 6.72, p < .01$
Self-rated proficiency for English					
Speaking	8.89 (1.69)	7.53 (2.19)	9.48 (1.14)	8.59 (1.43)	$F(3, 106) = 7.97, p < .01$
Comprehension	9.04 (1.50)	8.04 (2.06)	9.67 (0.90)	9.02 (0.91)	$F(3, 106) = 7.20, p < .01$
Self-rated proficiency for non-English language					
Speaking	7.68 (2.31)	8.14 (2.11)	5.55 (2.77)	6.69 (2.94)	$F(3, 106) = 6.50, p < .01$
Comprehension	8.14 (1.94)	8.56 (1.81)	6.83 (2.59)	7.72 (2.32)	$F(3, 106) = 3.67, p < .02$

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.
[b] Sample sizes are provided for these variables because participants reporting "never" in any of the bilingual history variables were not included in the analysis. Therefore, degrees of freedom for the error term differ between groups.

group became active bilinguals later than the other bilingual groups, but not significantly later than UL. There was no statistically significant difference in age of active bilingualism between BH, UH and UL bilingual groups.

Self-rated proficiency in bilinguals' two languages has often been used as a proficiency measure in bilingual research. In the present LSBQ, participants were asked to rate their English and non-English language proficiency relative to a native speaker in each language. These variables were skewed and, when included as four of the eight variables in the initial factor analysis, were not well-defined by the extracted factors. The final model excluded these self-rated proficiency variables to achieve an internally consistent model with two non-orthogonal factors. It is worth re-visiting these self-rated proficiency scores in the framework of these extracted factors, namely bilingual usage and English vocabulary. These proficiency ratings are shown in Table 6. One-way ANOVAs showed significant bilingual subgroup differences in all self-rated proficiency scores. For self-ratings on speaking and understanding English, the pattern of group differences coincided with that found for the English proficiency levels. In other words, regardless of bilingual usage, bilinguals with high English vocabulary scores rated themselves reliably higher in proficiency than bilinguals with lower English vocabulary scores. Post-hoc comparisons on self-ratings of the non-English language proficiency revealed a pattern of difference similar to the categorization of bilingual usage. Bilinguals with balanced usage between two languages rated themselves higher in proficiency in both speaking and comprehending the non-English languages.

To further explore the reliability of bilingual participants' self-rated proficiency and their actual performance on formal proficiency tasks, correlational analyses were conducted. In the present study, formal proficiency was only measured in English. Since English could be bilingual participants' L1 or L2, correlations were calculated separately for bilinguals. Overall, PPVT and EVT standard scores correlated with all bilinguals' self-ratings in English (speaking, comprehending, reading and writing), $rs(110) > 0.41$, $ps < .0001$. For bilinguals with English as L1, their self-ratings for English were significantly higher than those of their peers with English as L2.

In order to examine the correlation between self-rated and formal proficiency in English, it was necessary to examine the same correlations separately by the language status of English (see Table 7). When the correlations were examined in the bilingual subgroups, there were stronger correlations between self-ratings and formal proficiency in bilinguals who reported English as L2, but only two weak correlations in bilinguals with English as L1. This was probably because self-rated proficiency in L1 often reached ceiling and so would not be expected to show significant linear relationships. When English was L2, self-rated proficiency can be used as reasonable assessment of the participants' language proficiency.

Table 7. Correlations between self-rated and formal proficiency in English separately for bilinguals with English as L1 and L2.

	PPVT	EVT
Bilinguals with English as L1 (n = 53)		
Speaking	.15	.26
Comprehension	.17	.32*
Reading	-.00	.18
Writing	.09	.29*
Bilinguals with English as L2 (n = 57)		
Speaking	.42**	.46**
Comprehension	.38**	.37**
Reading	.46**	.37**
Writing	.49**	.40**

* $p < .05$ ** $p < .005$

Discussion

The present study confirmed that bilingualism is not a unidimensional construct. Moreover, the dynamic nature of bilingualism was captured quantitatively and confirmed qualitatively in terms of subgroup comparisons. Variables from a language and background questionnaire were included as measurements to explore the nature of bilingualism. Exploratory and confirmatory factor analyses showed that these variables loaded on two distinct but related factors. These factors were labeled as bilingual usage and English vocabulary, two bilingual dimensions proposed to be the driving sources of the opposing forces observed in bilingual research. Bilingual participants were categorized into high and low levels of these two factors, creating four bilingual profiles varying in levels of bilingual usage and English vocabulary. Demographic and language background comparisons revealed group differences consistent with expected variation in bilingual usage and English vocabulary.

Results from the factor analysis confirmed the complex nature of bilingualism. More importantly, it demonstrated quantitatively that bilingualism is not a categorical variable. Previous research comparing monolingual and bilingual participants has often indexed their bilingual participants' "levels of bilingualism" from self-reported proficiency in both languages. In fact, these bilinguals' language characteristics were often described qualitatively and only frequency data was reported. The present study extends qualitative bilingual profiles to quantitative dimensions. Using multivariate techniques, multiple variables pertaining to bilingual characteristics were considered simultaneously. Each bilingual participant was eventually assigned indices for each factor contributing to an individual's bilingual experience.

Unlike previous research, the present study included a large number of bilinguals with heterogeneous bilingual experience and linguistic backgrounds in the factor analysis. Although this increases the generalizability of the results, lack of homogeneity in the sample prohibits the examination of the proficiency in both bilinguals' languages. The bilingual usage factor relied on data obtained from the VAS on how "balanced" the participants were in using both languages on a daily basis. However, the vocabulary factor measured receptive and expressive vocabulary in only one language, English, which could be bilingual participants' L1 or L2. It is logical to assume that L1 proficiency, even in bilinguals, was at (near) native level and should show low variance. The four bilingual subgroups also differed significantly in the proportion of participants who reported English as their L1. Therefore, whether English was L1 or L2 could potentially confound English vocabulary scores. If the status of English as L1 moderated the relationship between the two extracted bilingual experience factors, then significantly different correlations between the factors should be observed for those with English as L1 and those with English as L2. To check this point, correlations between factors were calculated for bilinguals who reported English as L1, r (53) = 0.15, *ns* and those who reported English as L2, r (57) = 0.04, *ns*. In both cases, the correlations between bilingual usage and English vocabulary were not significantly different from zero. Therefore, it is safe to conclude that status of English did not moderate the relationship between the two factors. Nonetheless, bilinguals with English as L1 did have different levels of bilingual usage, t (104) = -9.20, $p < .0001$, and English vocabulary, t (106) = -5.38, $p < .0001$, relative to their peers who reported English to be L2. This difference was likely to be captured by the bilingual subgroups.

Another interesting finding from the present study was that self-rated proficiency in English and the non-English language reflected test levels of English vocabulary and bilingual usage respectively. In the present bilingual sample, self-rated proficiency for the non-English language was reflected in the subgroups of bilingual usage. The unbalanced bilingual groups (UH and UL bilinguals) showed lower ratings for their non-English language. On the other hand, bilinguals with high English proficiency (BH and UH bilinguals) rated themselves closer to native English speakers' level compared to bilinguals with lower English formal proficiency (BL and UL bilinguals). Marian, Blumenfeld and Kaushanskaya (2007) reported that self-rated proficiency in L2 correlated with formal proficiency measures in L2. The present study had similar findings. Correlations between self-ratings and formal proficiency were only moderate and reached statistical significance only in bilinguals who reported English as L2. The lack of correlation in bilinguals reporting English as L1 could be a consequence of near-ceiling ratings for L1. On the other hand, correlations between bilingual usage and self reported proficiency for non-English language were followed up separately as a function of the status of English as L1 or L2. Significant relationships between bilingual usage and the non-English proficiency were only observed in bilinguals who reported English as their L2, and not for those who reported English as L1. These correlations suggest that self-rated proficiency is only accurate when assessing the self-ratings for L2 in bilinguals.

The two extracted factors in the factor analysis were affected by the status of English in bilinguals because only English vocabulary was formally measured. The strength of the present study is the large sample size and heterogeneity of the bilingual sample. However, its strength is also its weakness. With a large and heterogeneous sample with very diverse linguistic background, it was almost impossible to measure proficiency formally in both L1 and L2. In addition, language proficiency should not be only limited to vocabulary. Nevertheless, compared to other aspects of language, for example, morphology, grammar and pragmatics, vocabulary of English is more readily measured by standardized tasks. Standardized tasks increase the validity of the factors in statistical analysis. The objective of conducting the factor analysis was to categorize bilinguals quantitatively and systematically according to their language experience. In subsequent analyses, different subgroup performance in executive functions can be attributed to these specific experiences of the subgroups. Therefore, for the purpose of the present report, formal measurement of English vocabulary was sufficient to categorize a large group of bilinguals for further examination of these subgroups' varying dimension on executive functions.

In summary, the present study suggested that the dimensions underlying bilingualism were not simple and should not be deemed orthogonal. To tease apart the sources of the opposing forces observed in bilingual research, two dimensions depicting specific bilingual experiences, namely bilingual usage of two languages and English vocabulary, were identified. These two specific bilingual experiences were proposed to be the driving forces of the divergent findings comparing monolinguals and bilinguals, i.e., bilingual advantage in cognition but bilingual disadvantage in language. A heterogeneous sample of bilinguals was categorized based on these related experiences. Across-group comparisons confirmed that these subgroups varied along these dimensions. In subsequent reports, these subgroups of bilinguals are compared in verbal and nonverbal tasks. Bilingual usage and English vocabulary are expected to interact and contribute to the bilingual advantage and disadvantage in nonverbal and verbal tasks.

Chapter 3. Comparing typical bilinguals and monolinguals

The bilingual subgroups established in Chapter 2 showed different characteristics in terms of their bilingual experience, such as the balance in usage between languages, English formal proficiency, bilingual history, and self-rated proficiency of both languages. If bilingualism results in changes in cognition, then differences in bilingual experience should also affect the nature of these changes. Two opposing forces, positive cognitive control and negative linguistic representations, were proposed to drive the contradictory cognitive and linguistic findings in bilingual research. While bilinguals have been shown to perform better than monolinguals in nonverbal executive functioning tasks, they usually perform poorer on tasks that require verbal responses or linguistic processing. Previous research comparing bilinguals' performance to monolinguals suggested that differences in performance (advantage in nonverbal cognitive tasks, disadvantage in language tasks) were attributed to bilingualism (for review of advantages, see Bialystok, 2007a; for disadvantages, see Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Gollan, Fennema-Notestine, Montoya, & Jernigan, 2007; and Ivanova & Costa, 2008).

So, how can bilingualism be responsible for the divergent results? If bilingualism is viewed as a dynamic multi-dimensional construct, then specific features of bilingualism could potentially be allied with these opposing forces and explain the contradictory results observed in bilingual research. Although it is more convenient in research design to have two groups of participants differing in their language experience, researchers have suggested that bilingualism should not be viewed as a categorical variable (Bialystok, 2001; Butler & Hakuta, 2004). To date, however, there is no empirical study examining the diverse components of bilingual experience and their divergent influences on the two opposing forces identified in bilingual research.

In the literature review, two dimensions of bilingual experience, namely proficiency in the two languages and balance of functional usage between languages, were proposed to be the driving forces for the contradictory results from bilingual research. In Chapter 2, these two dimensions were established quantitatively based on self-reported usage between two languages and standardized proficiency measures of English. As expected, these two dimensions of bilingualism were not independent of each other. Therefore, the factor analyses reported in Chapter 2 allowed these two factors to correlate with each other. Bilingual participants were categorized into four subgroups varying in levels of proficiency of English and balance of usage between their two languages. Due to the correlation between these two dimensions, predictions regarding verbal and nonverbal performance could not be reflected solely in main effects, but rather in the interaction between balance of usage of two languages and proficiency in English. The interaction between these two factors was expected to differ for nonverbal and verbal performance.

In the present chapter, the balanced bilinguals with high English proficiency (BH bilinguals) are compared to monolinguals in order to investigate whether there are group differences in the nonverbal and verbal tasks. These bilinguals were those who had balanced usage of both languages and similar level of English vocabulary as monolinguals. In the next chapter, all the bilingual subgroups are compared to each other as well as to the monolingual group in both nonverbal and verbal tasks. By first comparing the most contrasting groups (BH bilinguals and monolinguals), we intended to verify the group difference found in previous studies (for young adults, see Bialystok, Craik, & Ruocco, 2006; Bialystok, Craik, & Ryan, 2006; for middle-age adults and elderly, see Bialystok, Craik, Klein, & Viswanathan, 2004). Bilinguals included in these studies were balanced bilinguals who reported using both languages on a daily basis for a number of years and whose English vocabulary levels (measured by PPVT-R or PPVT-III) were comparable to the monolinguals included in the samples. Therefore, the BH bilinguals included in this chapter were similar to those who were recruited in previous studies in terms of balance usage of languages and English vocabulary level.

From previous studies examining nonverbal executive functions, bilinguals often outperformed monolinguals although the difference was subtle and did not always reach statistical significance. Therefore, the present study expected to replicate the pattern of results showing better performance of BH bilinguals relative to monolinguals in nonverbal executive functions. In contrast, bilinguals often show a disadvantage or no difference compared to monolinguals in verbal tasks. The majority of previous studies did not report level of formal or standardized proficiency of the language that was used to administer the tasks (e.g., Ivanova & Costa, 2008, only self-rated proficiency was reported), but language proficiency in bilinguals was an important determining factor in verbal task performance (Gasquoine, Croyle, Cavazos-Gonzalez, & Sandoval, 2007). Therefore, it is unclear whether disadvantages were due to low language proficiency which is a characteristic of bilingualism. From Chapter 2, BH bilinguals were shown to have similar English vocabulary levels to monolinguals. Therefore, for this group, bilinguals' performance was expected to be similar to monolinguals in general verbal tasks. In verbal task conditions that involved stronger demand of executive functions, BH bilinguals were expected to perform better than their monolingual peers.

Method

Participants

The bilingual participants who were identified as BH bilinguals (n = 22) in Chapter 2 and the monolinguals (n = 40) were included in this analysis.

Materials and Stimuli

In addition to LSBQ, PPVT-III and EVT, participants were given six tasks tapping spatial memory, nonverbal reasoning skills, verbal and nonverbal executive functions. Two background measures that assess participants' spatial memory and reasoning skills were included to establish the comparability of all participants on simple cognitive measures, namely the Spatial span subtest from the Wechsler Memory Scale-Third edition and the Cattell Culture Fair Test. The nonverbal tasks, flanker and faces tasks, were computerized tasks that gave response time and accuracy data as dependent variables. Stimuli in these tasks were pictorial and required a minimum amount of language processing. The verbal tasks, Verbal Fluency test from the Delis-Kaplan Executive Function system and sentence grammaticality judgment task, required participants to produce verbal output and make judgments about some sentences.

Spatial span subtest from the Wechsler Memory Scale-Third edition, WMS-III (also known as the Corsi Block, Wechsler, 1997). Ten blue blocks were presented on a white platform. All the blocks were secured on the platform and could not be moved.

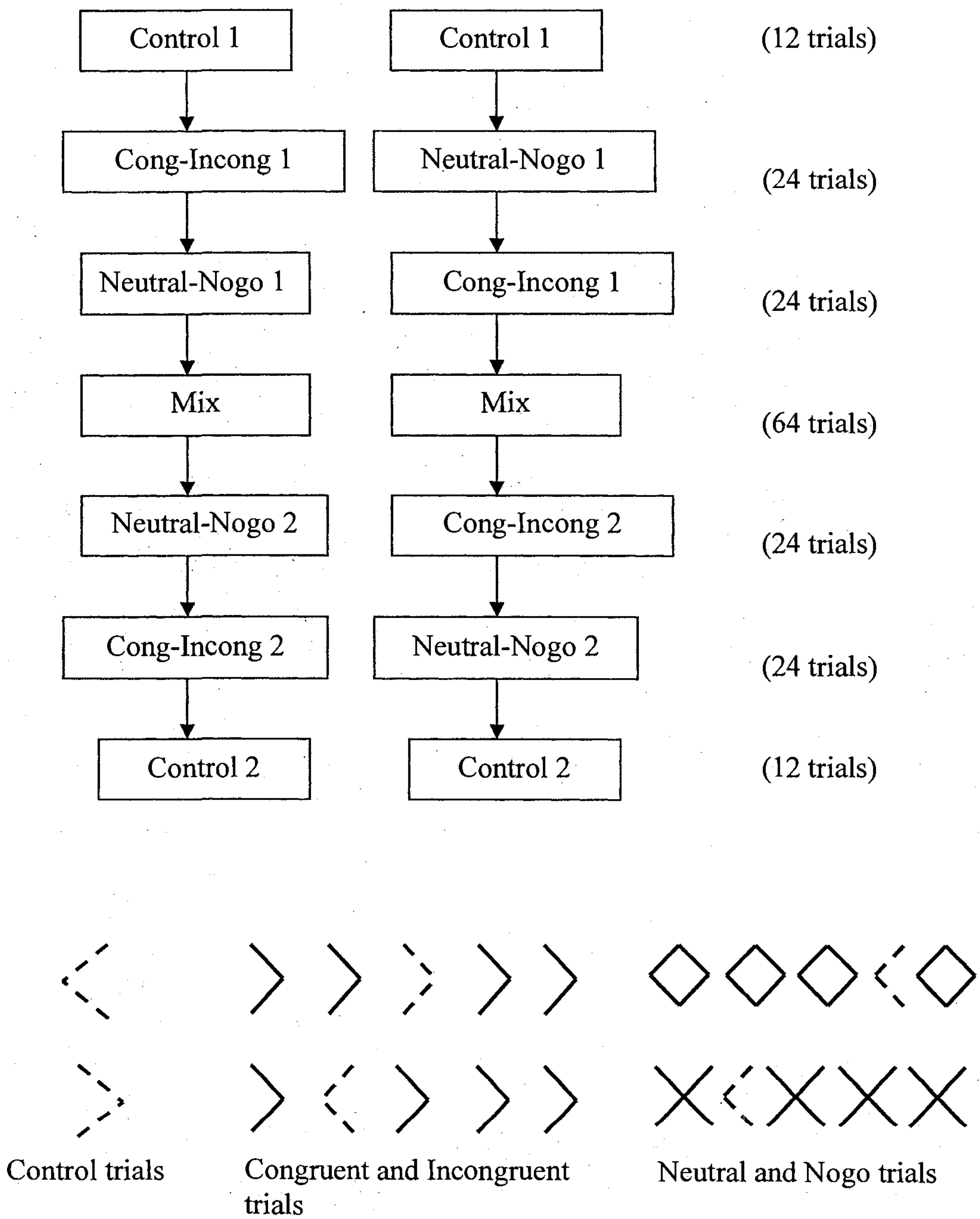
The numbered sides of the blocks were facing the experimenter during the administration of the task. Participants were asked to repeat a sequence tapped by the experimenter both in the same order and reverse order. Test items started with two blocks and increased one block at a time. For each length of test string, there were two trials using different numbers. Testing terminated when participants responded incorrectly to two trials at the same length. Raw scores were the number of correct trials in the forward and backward conditions. The maximum possible scores for forward and backward conditions were 14 and 16 respectively. Raw scores were transformed to standardized scores controlling for age according to tabled norms.

Cattell Culture Fair Test. (Cattell, 1957) Four tests were included in the Cattell Culture Fair Test. This test measures individual's nonverbal reasoning skills. Participants were asked to choose one (or two, in the second test) answer(s) from a number of alternatives to complete a series of pictures. Raw scores were the total number of correct trials across the four tests. Raw scores were transformed to standardized scores on a normal distribution with a reported mean of 100 and a reported standard deviation of 15.

Chevron Flanker Task. Participants were asked to respond to the direction in which a target chevron (in red) was pointing by pressing either one of two mouse buttons. The target chevrons were flanked by black distractors. There are altogether five types of trials. In a control trial, only one chevron pointing to left or right was shown at a time in the middle of the screen. In other trials, the target red chevron was flanked by four black distractors. The target red chevron was in one of the middle three positions. A congruent trial had all the black distracting chevrons pointing to the same direction as the target chevron, but an incongruent trial had the target and the distracting chevrons pointing to opposite directions. A neutral trial had the target chevron flanked by four black diamonds and the flankers in a nogo trial were crosses. Participants were told not to respond to nogo trials regardless of where the target chevron was pointing. Sample of these trials are shown in Figure 5.

Four conditions were included: (1) Control; (2) Congruent-Incongruent; (3) Neutral-Nogo; and (4) Mix. The Mix condition was a combination of all the trials presented in Congruent-Incongruent and Neutral-Nogo conditions. The four conditions were presented in seven blocks. Figure 4 shows two block orders along with the number of trials in each block and sample stimuli for each condition. The two block orders were randomly assigned to each participant. Since the categorization of bilingual participants was post hoc, it was impossible to counterbalance the number of participants in each group to perform on each order. Participants with an odd identification number were given order 1 while the others were given order 2. All trials were presented with a 500 ms fixation prior to the stimuli. The trials terminated either by subject response or automatic time-out after 2000 ms. All trials within each block were counterbalanced with right/left responses, types of trials (in all blocks except for Control) and positions of target chevrons (except for Control blocks). Presentation of trials within each block was randomized. Both response time and accuracy rates were recorded for analysis.

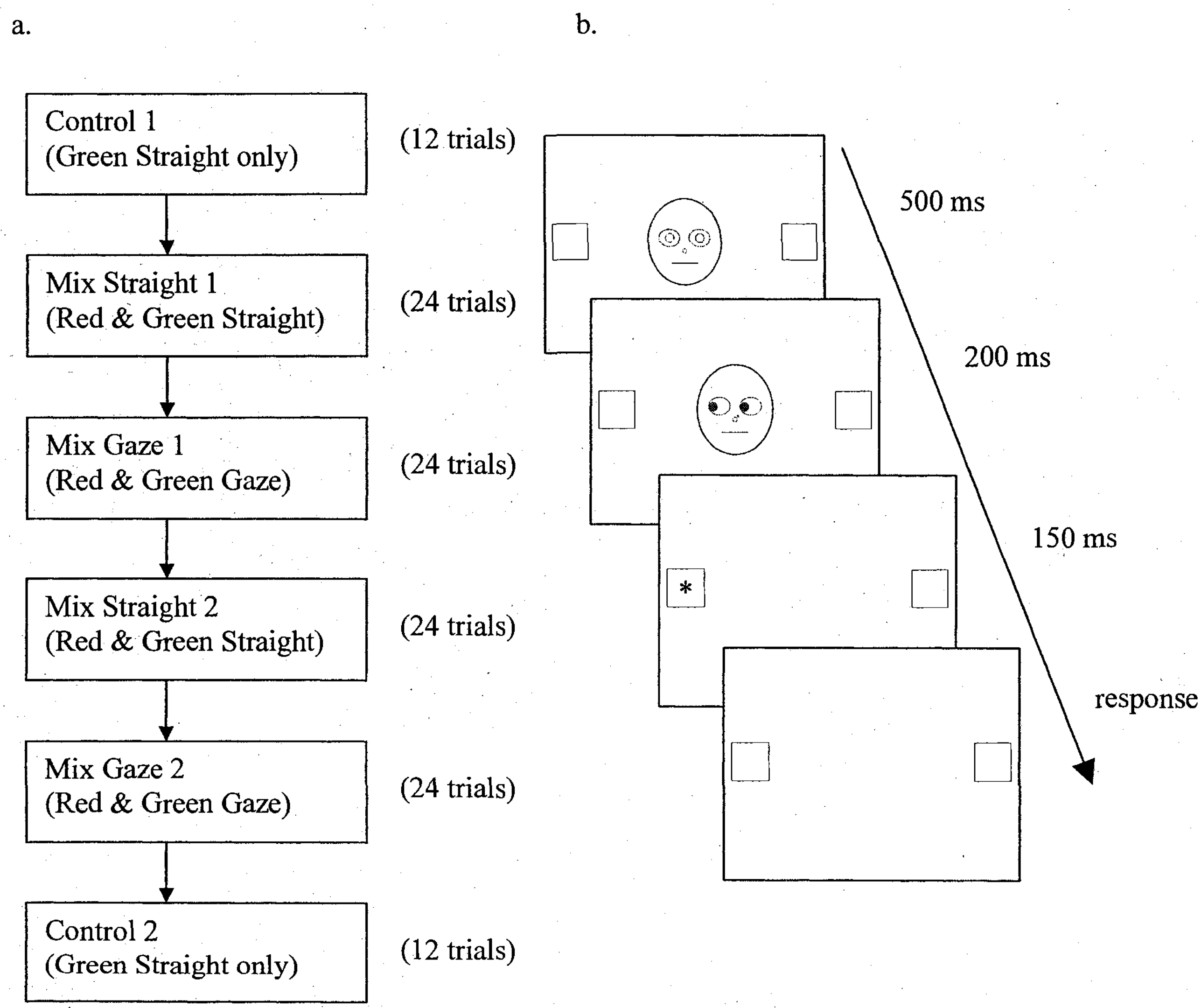
Figure 5. The order of presentation for Congruent-Incongruent blocks, Neutral-Nogo blocks, and Mix block. Dashed line is used to indicate the red target chevron.



Faces (Bialystok, Craik & Ryan, 2006). Participants were asked to respond to the position of an asterisk appearing in either the left or right box after seeing a face on the screen. Two response rules applied: If the face had green eyes, the participant should respond to the same side as the asterisk appeared; if the face had red eyes, the participant should respond to the opposite side as the asterisk appeared. Three conditions were included in the experiment: (1) Control condition in which there were only faces with green eyes looking straight; (2) Mix Straight condition in which faces with red and green eyes looking straight were mixed together; and (3) Mix Gaze condition in which faces with red and green eyes gazing to either left or right were mixed together. Figure 6 provides an overall presentation of blocks with number of trials in parentheses and the event presentation of each trial. The set-up of the experiment was similar to the one described for Chevron Flanker. Participants were asked to press one of the two mouse buttons located on their left and right sides. Similar to the Chevron Flanker task, both response time and accuracy rates were recorded.

Verbal Fluency test from the Delis-Kaplan Executive Function system. (Delis, Kaplan & Kramer, 2001). Participants were asked to produce as many words as possible in 60 seconds in English. They were asked to produce words that start with letters F, A, and S and in two categories, clothing items and girls' names. The letter task demanded phonemic retrieval and with the additional restrictions, this task was found to rely on executive functions. On the other hand, performance in category fluency reflected semantic retrieval, which is an overlearned verbal task.

Figure 6. Schematic presentation of the Faces task. (a) Block presentation with number of trials in parentheses. (b) Event presentation within each trial. The example shown here is a Green eye condition gazing towards the asterisk.



There were four restrictions for the letter conditions: (1) say different words, (2) no names of people, (3) no name of places, and (4) no numbers. The only restriction on category fluency conditions was to say different words. Responses were recorded on a digital recorder. Experimenters wrote down all the verbal responses after the testing session.

A research assistant who did not know the purpose of the study scored responses. During the scoring process, only the participants' unique identification numbers were provided. Raw scores were obtained by subtracting incorrect responses (words that did not start with the specified letter or not in the designated categories) and repeated words. Total raw scores were calculated for letter and category fluency conditions as the sum of the conditions (three for letter fluency and two for category fluency). These raw scores were transformed to standardized scores controlling for age from table entries in a standardized table reported in the examiner's manual (Delis, Kaplan, & Kramer, 2001).

Sentence grammaticality judgment task. Participants were asked to judge the grammaticality of 48 sentences. These sentences were categorized into four types: (1) Grammatical garden-path sentences; (2) Non-garden-path grammatical sentences; (3) Non-garden-path ungrammatical sentences; and (4) Nonsense sentences. Garden-path sentences are grammatical but have different levels of resolution of potential syntactic ambiguity. Twelve transitively-biased sentences were chosen from Osterhout, Holcomb & Swinney (1994) to serve as the garden-path sentences. These sentences included transitively-biased verbs, such as *saw, charge, forgot,* that created uncertainty regarding the role of the postverbal noun phrase. Despite the syntactic ambiguity, these sentences were all grammatical in structure. The other types of sentences were derivatives of these garden-path sentences (All the sentences are presented in Appendix C), resulting in 48 sentences in 12 contexts. Each sentence was shown for six seconds before a blank screen with a check mark and a cross appeared. Participants were instructed to decide whether the sentence they had just seen was grammatically correct, then indicate their decision by pressing either the left or right mouse button. The check-mark and the cross were included to minimize the demand for the remembering which side to press in order to indicate their responses. The next sentence appeared once a response was received. The 48 sentences were presented in four blocks. In each block, the type of sentences and responses to checkmark or cross were counterbalanced. Accuracy rates were obtained as dependent variables in this task.

The target stimuli were the garden-path sentences. Participants were told to judge the sentence grammaticality but the syntactic ambiguity embedded in the sentences was distracting. Therefore, in order to make a judgment on the grammaticality of these sentences, participants needed to isolate the syntactic ambiguity from the grammaticality of the sentences. The other types of sentences acted as controls for the garden-path sentences.

Table 8 provides a summary of the tasks, their related domain of processing and descriptive predictions for the comparisons between BH bilinguals and monolinguals. In general, the BH bilinguals were expected to perform better than monolinguals in the nonverbal executive functions tasks. Their enhanced performance could be reflected as

Table 8. Summary of tasks and corresponding predictions for comparisons in performance between BH bilinguals and monolinguals.

Task	Domain	Dependent variables	Prediction
Flanker Task	Nonverbal	RT and accuracy	BH bilinguals and monolinguals would attain similarly high accuracy rates, but difference in performance was expected in RT or cost analysis of RT. The expected direction was that BH bilinguals would be faster or suffer from smaller costs.
Faces Task	Nonverbal	RT and accuracy	Prediction was similar to Flanker Task
Verbal Fluency	Verbal	Number of words	BH bilinguals and monolinguals would produce similar number of words in the category fluency task. However, BH bilinguals were expected to produce more words in letter fluency task because of the increase demand for executive control.
Sentence judgment	Verbal	Proportion of positive judgment	BH bilinguals were expected to make more positive judgments for garden-path sentences because of the demand to dissociate the grammaticality of the sentences from its ambiguous syntactic structure. However, the two groups would make similar proportions of judgment for the other types of sentences.

faster response time or smaller percentage increase in response time costs analysis. In verbal tasks, the BH bilinguals were expected to perform similarly to monolinguals.

Procedures

Participants were first given the informed consent forms. Then the experimenter administered the LSBQ in a casual conversational manner. Other tasks were then administered in a fixed random order: faces, Cattell Culture Fair Test, sentence grammaticality judgment, spatial span subtest from WMS-III, verbal fluency test, PPVT-III, chevron flanker and EVT. At the end of the testing session, participants were given a brochure containing very general information about the study.

Three research assistants who helped in data collection were all well-trained in four steps: (1) being a participant in the experiment; (2) trained by the principal investigator; (3) shadowing the principal investigator; and (4) supervised by the principal investigator in the first three testing sessions. Furthermore, the principal investigator and the research assistants filled in a log book for every participant, reporting information such as each participant's identification number, date tested, time started, time finished and any other events that happened during the testing sessions.

Results

Data preprocessing and plan of data analysis

Data from the chevron flanker task, faces task and sentence judgment task were recorded in E-prime on a PC computer automatically when participants provided a response. They were preprocessed in a SAS macro programme to extract response time and accuracy rates for each individual. Data were pre-processed to obtain central tendency measures for each individual's response time for each type of trial. For response time data from the chevron flanker and faces tasks, central tendencies were calculated without incorrect trials. In addition, response times in the chevron flanker and faces tasks that were under 50 milliseconds (ms) or greater than 1500 ms were excluded from calculation of the central tendency because these times were either too short or too long and may not indicate the cognitive processes of interests. For the sentence judgment task, the proportion of correct sentences was calculated for each type of sentence. The macro programme helped preprocess data efficiently (160 participants' data in three tasks were processed in 3 minutes) and accurately (no manual processing of data was involved).

Response time data from the chevron flanker and faces tasks are reported in raw forms. The analysis reported below used both raw response time and percentage change relative to control trials as dependent variables. Control trials response time in each task was used to establish the baseline response time in the simplest trials for a specific task context. In this case, individual differences in baseline response time could be isolated and controlled for. Performance in all experimental tasks was analyzed in two steps. The first step included only the BH bilinguals and monolinguals and the results are reported in the present chapter. The second step included the other bilingual groups (BL, UH, UL) in addition to the BH bilinguals and monolinguals, and are reported in Chapter 4.

All analyses were performed using general linear models (GLM). GLMs were chosen over traditional Analysis of Variance (ANOVA) models because of the unequal sample sizes (Kutner, Nachtsheim, Neter & Li, 2005). The problem of unequal sample sizes could lead to heterogeneity of variances, which violates one of the assumptions of GLMs. Therefore, Welch's adjustment of degrees of freedom (Welch, 1951) was calculated for all one-way GLMs. Welch's solution simply adjusts the degrees of freedom for the error variance and does not change other aspects of the GLMs. This solution increases the statistical power to detect group difference if heterogeneity of variances occurred. If no heterogeneity of variance is detected then test results are the same as the GLMs. Therefore, Welch's solution is reported for all one-way GLMs as a more accurate picture of the group comparisons.

Background tasks

Table 9 presents the descriptive statistics on the background tasks for BH bilinguals and monolinguals. There was no group difference in performance for spatial span subtest of WMS-III, $F(1,59) = 2.1$, $MSE = 10.9$, $p = 0.15$. Participants remembered more correct trials in the backward condition compared to the forward condition, $F(1,59) = 8.0$, $MSE = 4.1$, $p < .007$, $\eta_p^2 = 0.12$, but this condition effect did not interact with group performance, $F(1, 59) < 1$. Cattell Culture Fair test performance was reported in age-corrected standardized scores. GLM showed no group difference between BH bilinguals and monolinguals, $F(1, 60) < 1$, confirming no a priori differences between the BH bilinguals and monolinguals in spatial memory and nonverbal reasoning skills.

Table 9. Mean scores (and standard deviations) for nonverbal background measures of the BH bilinguals and monolinguals.

Background variable	**BH**[a] (n = 22)	**M** (n = 40)
Forward Corsi Block	9.7 (2.9)	8.9 (2.7)
Backward Corsi Block	10.7 (2.7)	9.9 (2.8)
Cattell Culture Fair Test	117.0 (14.8)	113.3 (16.7)

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; M = Monolingual.

Nonverbal executive functions tasks

Chevron flanker task. Accuracy rates and response times for all types of trials are presented in Table 10. The accuracy rates for all trials in the task were at least 92%, so no statistical analysis was conducted on accuracy rates because of the lack of variance. Since accuracy rates were high, all differences observed in response time could not be attributed to speed-accuracy tradeoff.

Response time to control trials showed no difference between groups, $F_{Welch} < 1$. In the blocked conditions, response times for congruent trials were faster than for incongruent trials, $F(1,57) = 247.5$, $MSE = 337.9$, $p < .0001$, $\eta_p^2 = .81$; there was no group difference in raw response time, $F(1,57) = 2.7$, $p = 0.11$, and no group by trial type interaction, $F(1,57) = 1.6$, *ns.* Neutral trials in the neutral-nogo block also showed no significant group difference, $F_{Welch}(1,43) < 1$. Congruent, incongruent and neutral trials in the mixed blocked were analyzed in a two-factor group by trial GLM, which indicated a marginally significant group difference, $F(1,57) = 3.2$, $MSE = 19729.7$, $p < .08$, $\eta_p^2 =$

0.05, and a strong trial effect, $F(2, 114) = 109.3$, $MSE = 1039.1$, $p < .0001$, $\eta_p^2 = .65$, but no interaction, $F < 1$. The BH bilinguals responded faster than the monolinguals in the three types of trials in the mixed block. Within-factor contrasts showed that performance on the congruent trials was the fastest, followed by the neutral trials and the incongruent trials.

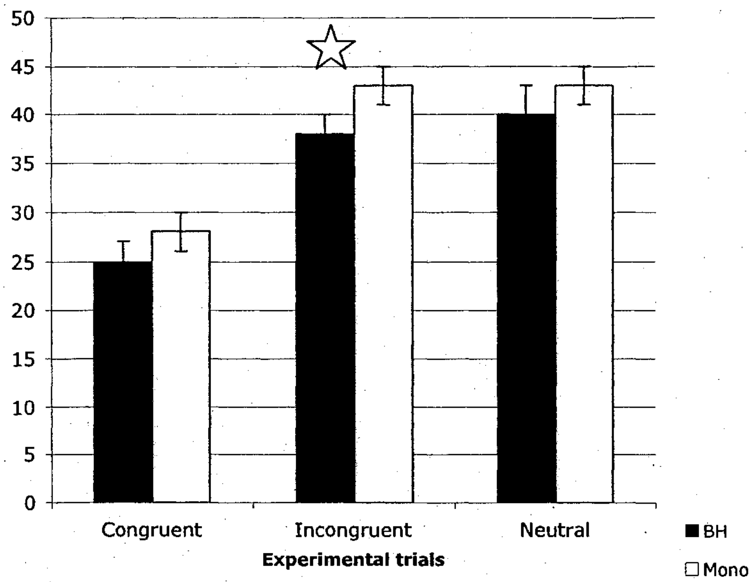
Table 10. Descriptive statistics of accuracy rates and response times (in ms) for performance in the Chevron flanker task for BH bilinguals and monolinguals.

Trial type	**Accuracy rates**[a]		**Response time**[b]	
	BH[c] (n = 22)	**M** (n = 40)	**BH** (n = 22)	**M** (n = 40)
Blocked				
Control	0.98	0.98	399 (11.3)	397 (8.1)
Congruent	1.00	0.99	497 (14.5)	504 (9.6)
Incongruent	0.95	0.96	533 (10.5)	565 (10.9)
Neutral	0.99	0.99	553 (16.4)	565 (12.7)
Nogo	0.98	0.98	--	--
Mixed				
Congruent	1.00	1.00	534 (16.0)	553 (13.6)
Incongruent	0.97	0.97	609 (14.5)	649 (16.3)
Neutral	0.99	0.99	571 (19.4)	601 (14.6)
Nogo	0.94	0.92	--	--

[a] Standard deviations are reported for accuracy rates.
[b] Standard errors are reported for response time.
[c] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; M = Monolingual.

Percentage changes in response times were obtained from the blocked and mixed conditions. In the blocked conditions, percentages increase in response times relative to control trials for congruent, incongruent and neutral trials were established to examine the costs in response time due to different types of flankers. Among the relative costs (see Figure 7), no group difference was observed for congruent trials, F_{Welch} (1, 49.4) = 2.1, *ns.,* or neutral trials, F_{Welch} (1, 30.0) < 1. Relative cost for incongruent trials showed a significant group difference, $F_{Welch}(1, 43.9) = 4.6$, $MSE = 82.0$, $p < .04$, $\eta_p^2 = .07$, in which BH bilinguals had a smaller cost than monolinguals. An additional cost between the incongruent and congruent trials was also found. This is the typical flanker effect (Eriksen & Eriksen, 1974) indicating the effect of congruency. As shown in Figure 8, there was no difference between BH bilinguals and monolinguals in the flanker effect, F_{Welch} (1, 32.5) < 1. In the mixed condition, mixing costs were examined. Percentage increases in response times for congruent, incongruent and neutral trials in mixed conditions were calculated using the blocked condition as baselines. Mixing costs were assessed to show the general cost in response time when a specific type of trial was intermixed with other trials, reflecting the flexibility of responding. Mixing costs are shown in Figure 9. There was no group difference in the mixing costs for congruent and incongruent trials, *Fs* < 1, *ns*, but BH bilinguals suffered smaller mixing costs for neutral trials than monolinguals, $F_{Welch}(1, 55.8) = 5.0$, $MSE = 61.7$, $p < .03$, $\eta_p^2 = .05$.

Figure 7. Flanker task, relative costs: Percentage increase in response times relative to control trials for blocked congruent, incongruent, and neutral trials



* Star indicated significant group difference between BH bilinguals and monolinguals in GLM with $\alpha = .05$.

Figure 8. Flanker task, relative costs: Percentage increase in response time for incongruent over congruent trials (blocked condition).

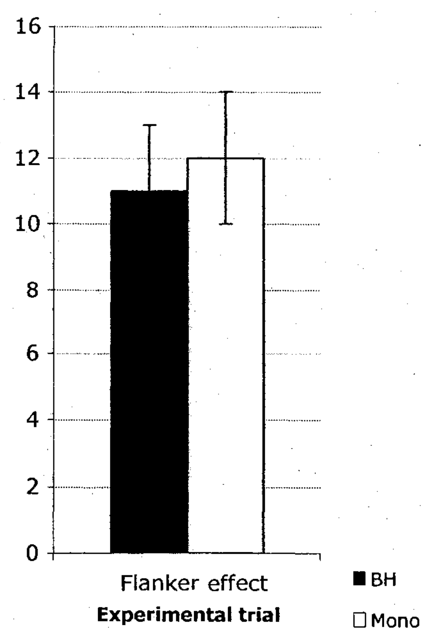
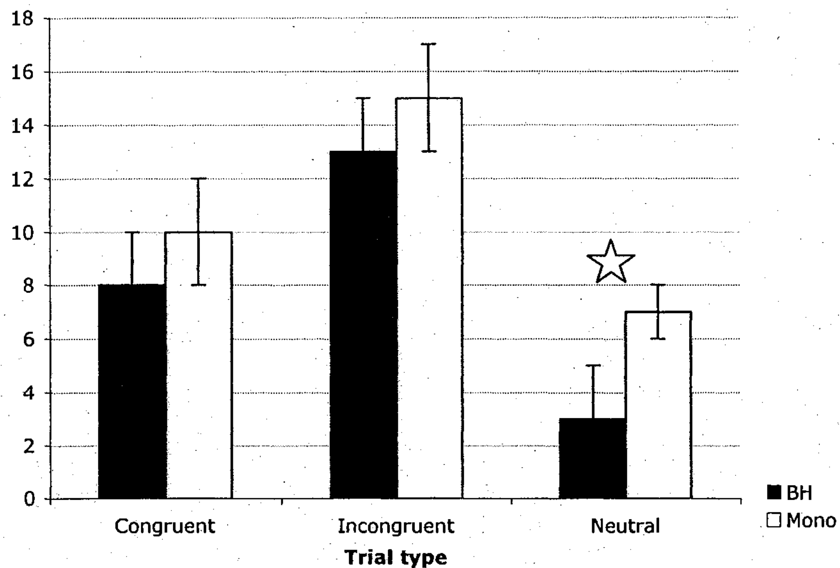


Figure 9. Flanker task, Mixing costs: Mean percentage increase in response time for mixing cost of congruent, incongruent and neutral trials relative to corresponding trial type in blocked conditions.



* Star indicated significant group difference between BH bilinguals and monolinguals in GLM with $\alpha = .05$.

Faces. Accuracy rates were close to ceiling for all groups in all conditions of the faces task (Table 11), so no further analysis was conducted on the accuracy data. Raw response time data are also shown in Table 11. There was a significant group effect on the mean response time for the control trials but only for green eyes looking straight, $F_{Welch}(1, 33.56) = 6.9$, $MSE = 2924.9$, $p < .02$, $\eta_p^2 = 0.16$, indicating that monolinguals responded faster than the BH bilinguals.

In the mixed straight condition, the trials with green (respond to same side of asterisk) and red eyes (respond to opposite side of where the asterisk appeared) were analyzed in a group x colour GLM. There was a significant difference for colour, $F(1, 59) = 51.6$, $MSE = 600.4$, $p < .0001$, $\eta_p^2 = .47$, with responses to green eye trials faster than red eye trials, but no difference between groups, $F(1, 59) = 1.3$, *ns*, or no colour by group interaction, $F(1, 59) < 1$, *ns*. In the mixed gazed condition, the four types of trials were analyzed in a three-factor GLM, group x colour x gaze direction. Significant effects were found for colour, $F(1, 59) = 60.6$, $MSE = 1629.6$, $p < .0001$, $\eta_p^2 = .51$, and gaze direction, $F(1, 59) = 7.6$, $MSE = 1728.7$, $p < .001$, $\eta_p^2 = 0.11$. No group effect or two-way or three-way interactions reached statistical significance.

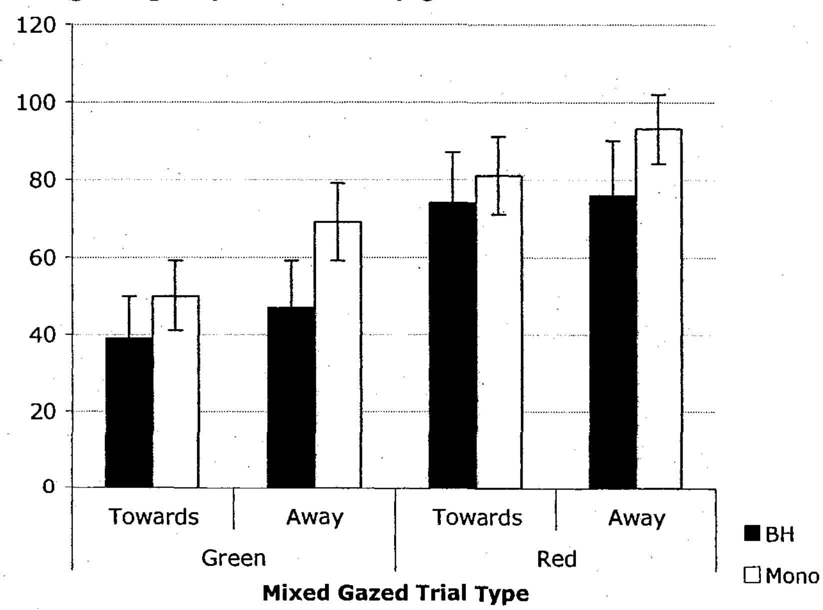
Table 11. Descriptive statistics for accuracy rates and response times (in ms) for all types of trials in the faces task.

	Accuracy rates		**Response time**[a]	
Trial type	**BH**[b] (n = 22)	**M** (n = 40)	**BH** (n = 22)	**M** (n = 40)
Blocked control				
Green eyes	1.00	0.98	189 (13.9)	147 (7.4)
Mixed Straight				
Green eyes	0.95	0.94	249 (27.3)	217 (16.8)
Red eyes	0.98	0.95	287 (26.9)	245 (16.0)
Mixed Gazes				
Green-Towards-asterisk	0.96	0.95	263 (32.0)	224 (18.2)
Red-Away-asterisk	0.96	0.96	322 (32.0)	280 (17.1)
Green-Away-asterisk	0.98	0.93	276 (30.9)	254 (20.6)
Red-Towards-asterisk	0.98	0.96	319 (30.9)	264 (17.1)

[a] cell values report means and standard errors for response time.
[b] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; M = Monolingual.

Since the monolinguals had faster performance in the control trials (Blocked green eyes looking straight), percentage increase in response times were calculated for the four types of trials in the mixed gaze condition by subtracting response time in the blocked control trials (green eyes looking straight) from response time in the mixed gaze trials. These relative changes in percentages are presented in Figure 10. The group x colour x gaze analysis was repeated for these percentage increases. Similar to using the response times as dependent variables, there were robust colour, $F(1, 59) = 70.6, p < .0001$, and gaze main effects, $F(1, 59) = 8.3, p < .006$, but no significant group main effects, two-way interactions, or three-way interactions.

Figure 10. Faces task: Relative costs of experimental trials compared to blocked trials with green eye looking straight by colour and by gaze direction.



Verbal executive functions tasks

Verbal fluency. Means and standard deviations of verbal fluency performance are reported in Table 12. Each condition was submitted to one-factor GLMs with group as the factor. In the letter tasks, there were significant group difference for the letters F, $F_{Welch}(1, 56.3) = 8.4$, $MSE = 15.7$, $p < .02$, $\eta_p^2 = 0.1$, and S, $F_{Welch}(1, 34.9) = 6.2$, $MSE = 7.6$, $p < .01$, $\eta_p^2 = 0.11$, but not A, $F_{Welch}(1, 52.2) = 2.8$, *ns*. In the category tasks, BH bilinguals performed similarly to monolinguals on both clothing item, $F_{Welch}(1, 42.5) < 1$, and girl's name, $F_{Welch}(1,34.75) = 1.7$, *ns*. Standardized scores controlling for age were computed for all conditions in letter and category tasks separately. These scores are shown in Figure 11.

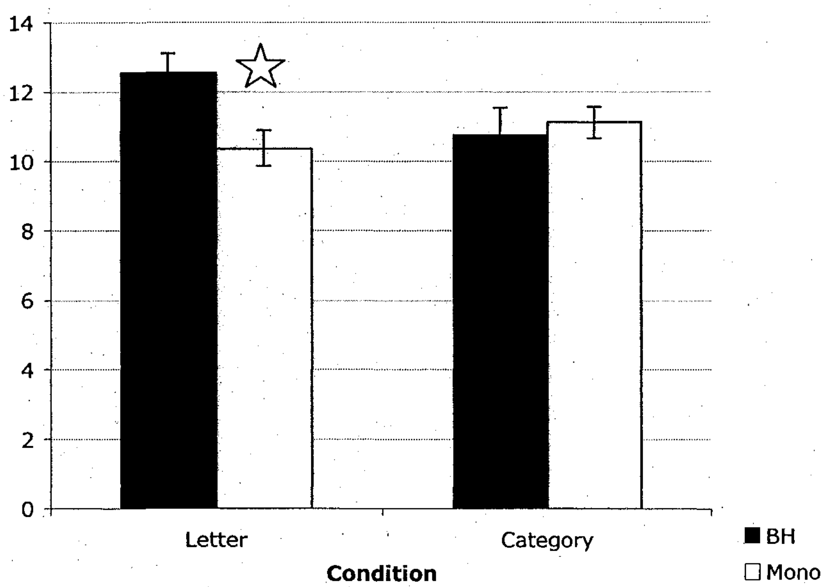
Table 12. Descriptive statistics for all conditions in verbal fluency task

Condition	**BH**[a] (n = 22)	**M**[b] (n = 39)
Letter[c]	14.8 (3.7)	12.4 (4.0)
F	15.4 (3.0)	12.6 (4.4)
A	12.3 (3.4)	10.6 (4.2)
S	16.8 (4.6)	13.9 (3.5)
Category[c]	19.9 (5.4)	20.4 (4.6)
Clothing item	18.5 (4.7)	17.5 (4.5)
Girl's name	21.2 (6.0)	23.2 (4.6)

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; M = Monolingual.
[b] One subject's data could not be collected due to equipment failure.
[c] Cells show mean number of words produced and standard deviations across all conditions for letter and category tasks.

There was no overall group difference, $F(1,60) = 1.6$, *ns*, or task difference, $F(1,60) = 1.6$, *ns*, but a significant group by task interaction, $F(1,60) = 9.69$, $MSE = 4.66$, $p < .003$, $\eta_p^2 = 0.14$. Simple effects analysis suggested that BH bilinguals outperformed monolinguals in the letter task, $F_{Welch}\,(1, 51.5) = 8.9$, $MSE = 9.3$, $p < .005$, $\eta_p^2 = 0.12$, but both groups had similar performance in the category task, $F_{Welch} < 1$.

Figure 11. Age-corrected standardized scores of letter and category conditions in verbal fluency tasks.



* Star indicated significant group difference between BH bilinguals and monolinguals in GLM with $\alpha = .05$.

Sentence grammaticality judgment task. The descriptive statistics of the percentage of judging the presented sentences as grammatically correct are shown in Table 13. Instructions were to judge whether the sentences were grammatically correct. Therefore, the percentages of judging the sentences as grammatically correct were reported. There was no difference between the BH bilinguals and monolinguals in judgment for the garden-path sentences, non-garden-path ungrammatical sentences and nonsense sentences, *Fs* < 1, but a marginally significant difference in judging the non-garden-path grammatical sentences, $F_{Welch}(1, 45.9) = 3.7$, $MSE = .01$, $p = .06$, partial $\eta^2 = 0.06$, suggesting the BH bilinguals were more likely to judge this type of sentence as correct than monolinguals.

Table 13. Mean and standard deviation of percentage of judgment considering the presented sentences as grammatically correct.

Type of Sentences	**BH**[a] (n = 22)	**M**[b] (n = 39)
Garden-path (GP)	66 (14)	64 (13)
Non-GP grammatical	91 (9)	86 (10)
Non-GP ungrammatical	12 (13)	9 (8)
Nonsense	7 (9)	9 (8)

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; M = Monolingual.
[b] One participant failed to complete the task.

Discussion

The present study compared two groups of young adults with different language experiences in verbal and nonverbal executive functions. The BH bilinguals included in this study had relatively high usage of their non-English language and high level of English vocabulary. In fact, their performance on formal English receptive and expressive vocabulary tasks was at the same level as the monolinguals. In other words, the main difference between the BH bilinguals and the monolinguals was in their everyday language experience. Results from the present study largely replicated the bilingual advantage observed in earlier studies that included young bilinguals with a high level of English proficiency. However, when language processing was involved in an executive function task, the pattern of results differentiated between the conditions that demanded a higher level of cognitive control (e.g., letter fluency) and the conditions that only needed access to lexical items (e.g., category fluency).

Previous studies often included bilinguals who had characteristics similar to those of the BH bilinguals in the present study (Bialystok, Craik, & Ruocco, 2006; Bialystok, Craik, & Ryan, 2006). These bilinguals often performed better in executive functioning tasks that did not require language processing. This advantage was observed in conditions that demanded the highest level of cognitive control, e.g., in conditions that needed conflict resolution or suppression of irrelevant information. Consistent with these studies, in the chevron flanker task, the bilinguals responded faster than the monolinguals to all experimental trials that embedded different kinds of flankers. In the blocked trials, the percentage change in response time relative to control trials for all experimental trials was smaller in BH bilinguals than in monolinguals. Of these comparisons, only the cost of incongruent flankers reached statistical significance. In incongruent trials, the distracting flankers provided conflicting information to the target arrows. The smaller costs indicate that the BH bilinguals were more efficient in suppressing the distracting information and more able to focus on the information given in the target chevrons. In the mixed block, there was a marginally significant group difference in which BH bilinguals responded faster than monolinguals in all types of trials. In order to perform well in the mixed block, participants needed to respond flexibly because of the different types of flankers and occasional nogo trials. When examining the percentage change in response time for the mixing costs, the BH bilinguals again suffered less than monolinguals in all costs although only the cost of neutral trials reached statistical significance.

In another nonverbal executive function task, the faces task, there was no significant group difference in any conditions although trends were all in the predicted direction. Why were the patterns of results different for the two nonverbal executive functions tasks? First, the chevron flanker task was designed to measure the ability to suppress distraction with minimal demand for remembering rules. The chevrons were symbolic, but they provide transparent and non-ambiguous information about their pointing direction. Therefore, there was no need to remember where to press (i.e., the load on memory was minimal) but participants needed to be attentive to both the target and the flankers (i.e., the load on attention was maximized). In other words, solving the flanker task successfully required attention. Unlike the flanker task, the faces task required remembering which rule applied to the colours of the eyes (green eyes indicated responding to the same side as the asterisk, red eyes indicated the opposite side) in addition to paying attention to the side on which the asterisk appeared. The processing was sequential in the faces task but simultaneous in the flanker task. From Chapter 1, it was suggested that bilingual experience mostly enhances control of attention, not how information is processed and stored. Therefore, it was not surprising to have divergent results in the two nonverbal executive functions tasks that examined two different cognitive constructs.

Another possibility is related to technical aspects of the design of event presentation in the two tasks. In the chevron flanker task, the onset of response time recording was initiated at the same time as the presentation of the stimuli. Therefore, the response time included the following processes: (1) identifying the target; (2) deciding to make a response or inhibiting it; (3) focusing on the target and making a correct choice. These three processes may not be performed sequentially, but all were needed to perform successfully. In contrast, the processes involved in the faces task required an association of response rules prior to making a decision, especially in the trials involving gazes: (1) remember the colour of the eyes; (2) pay attention to where the asterisk appeared; (3) prepare a response according to the colour of the eyes in step (1); and (4) make a correct response. The onset of response time recording started after the presentation of the asterisk, i.e., after step (2). The intention of starting the response time recording at this event was to eliminate the time to remember the colour of the eyes. Nonetheless, it was not possible to isolate the time needed in retrieving the rule in step (3). Therefore, the response time recorded in the faces task reflected both attention and memory processes, while the response time recorded in the chevron flanker task primarily reflected attention.

As a consequence, the additional processes mixed in the recorded response time to solve the faces task were not influenced by bilingualism.

From past research, it was shown that the difference between groups is more apparent in children (Bialystok & Martin-Rhee, 2008) and the elderly (Bialystok, et al., 2004). Particularly in Bialystok et al. (2004), the difference between groups was significant but much smaller in the middle-age groups than in the elderly. The young adults included in the sample were at their peak of performance in cognitive and motor aspects; therefore group difference in this age group would be dampened. Overall, results from one of the two nonverbal executive functions tasks conformed to previous findings that bilinguals suffered less from interference, especially in the most demanding situation.

Turning to verbal tasks, we see that past research often reported that bilinguals performed worse or similarly as monolinguals (for verbal fluency, see Gollan, Montoya, & Werner, 2002; for picture naming latency, see Ivanova & Costa, 2008). Surprisingly, contrary to previous findings, the BH bilinguals outperformed the monolinguals in one condition of a verbal task in the present study. In the verbal fluency task, BH bilinguals produced more words than monolinguals in the letter condition; but in the category condition, the two groups produced the same number of words. Previous research involving monolinguals and bilinguals often reported the participants' characteristics, but not their formal language proficiency. It is well established that bilinguals possess a smaller vocabulary pool than monolinguals (for children, see Bialystok & Feng, in press;

Oller et al., 2007; for young adults, Portocarrero, Burright, & Donovick, 2007). Therefore, bilinguals' lower performance could result from bilingualism and/or lower vocabulary. In the present study, participants' vocabulary level was assessed formally. Results from chapter 2 showed that the BH bilinguals had the same level of vocabulary as their monolingual peers. In this case, any group difference that emerged could then be attributed to bilingualism, not their smaller vocabulary.

The verbal fluency task was chosen because the two conditions demanded different levels of executive functioning. In letter fluency, the demand for control is relatively higher than it is in category fluency because phonemic production is not an over-learned task (Strauss, Sherman, & Spreen, 2006). While the letter fluency task requires proficiency and executive functions, the category fluency task requires primarily proficiency. After matching for proficiency, BH bilinguals outperformed monolinguals in the letter fluency task, suggested their superior performance in executive functions. In addition, their similar level of proficiency in English as the monolinguals was replicated in their category fluency performance. These results indicate that bilingualism boosted verbal fluency provided that the proficiency levels of the monolinguals and the bilinguals were equivalent.

Finally, in the grammaticality judgment task, BH bilinguals and monolinguals judged the grammaticality of the garden-path sentences similarly. BH bilinguals judged the grammatical sentences correctly more often than their monolingual peers. The sentences included were designed to act as another task that involved both executive functions and proficiency. This task was proposed to assess the syntactic level of language processing rather than the lexical level tested in the verbal fluency task. In order to judge the garden-path sentences as grammatically correct, participants needed to inhibit the awareness that the syntax of the sentence was ambiguous and they should only pay attention to the grammaticality. Despite the BH bilinguals' more efficient performance in the nonverbal executive functions task, the cognitive advantage did not extend to syntactic judgments at the level of sentence processing. However, judgments of the garden-path sentences were similar for groups and were also similar to previously reported judgments (66% reported in Osterhout, Holcomb, & Swinney, 1994).

These results confirm the presence of two opposing forces in bilingualism, namely positive force in nonverbal executive functions and negative force in verbal tasks. Unlike previous studies in which these two forces were investigated separately, the present chapter examined these two forces in the same sample of bilinguals. In nonverbal executive functions, the BH bilinguals responded faster and suffered less than monolinguals in the face of distraction. They were also more efficient in making a response when multiple types of trials were mixed together. In verbal tasks, the BH bilinguals performed similarly to the monolinguals in the majority of the conditions. This is not surprising because they were matched in formal English vocabulary. However, BH bilinguals outperformed monolinguals in the condition that required both executive functions and proficiency. Essentially, bilingualism enhanced lexical retrieval if proficiency was well controlled; hence, the bilingual disadvantage in verbal tasks reported in previous studies was a consequence of lower proficiency, not bilingualism. Although bilingualism is often associated with low proficiency, these two constructs can be dissociated. In the next chapter, the other bilingual groups were included to examine the influence of varying levels of the specific bilingual experiences, namely balanced usage of languages and English vocabulary, on verbal and nonverbal executive functions.

Chapter 4. Including additional bilingual subgroups

In Chapter 3, the BH bilinguals were compared to monolinguals on a series of verbal and nonverbal tasks. The pattern of results from the nonverbal task performance replicated the bilingual advantage reported in earlier studies, but the verbal tasks showed similar performance in the BH bilinguals and the monolinguals. The verbal task result was possibly a consequence of similar English proficiency in the two groups. In the condition that required both high language proficiency and executive functions, e.g., the letter fluency task, the BH bilinguals performed better than the monolinguals. These positive and negative influences of bilingualism on executive functions replicated earlier findings and pointed to the role of opposing forces in bilingualism. The next logical step to dissect the bilingual influence on executive functions is to examine whether specific bilingual experiences entail these opposing forces differentially.

The BH bilinguals had similar language experiences as participants in previous studies in which a bilingual advantage was found (Bialystok, Craik, & Ruocco, 2006; Bialystok, Craik, & Ryan, 2006). Both the BH bilinguals and the bilinguals recruited in the previous studies reported high usage of a non-English language at home but predominant use of English outside their home environment. Moreover, they had levels of receptive and expressive English vocabulary comparable to those of their monolingual peers. Most importantly, as reported in Chapter 2, only 22% of the BH bilinguals reported having English as their first language. The implication is that despite their high usage of a non-English language and the fact that English was not their L1, BH bilinguals reached the same level of English proficiency as their English-speaking monolingual peers. Therefore, these BH bilinguals were high in the two specific bilingual experiences identified in the literature review, namely, functional usage of both languages and high proficiency level of English.

Three other groups of bilinguals were identified in Chapter 2: Balanced bilinguals with low English vocabulary (BL), unbalanced bilinguals with high English vocabulary (UH) and unbalanced bilinguals with low English vocabulary (UL). These bilinguals differed from the BH bilinguals in having either unbalanced usage of two languages or low levels of English proficiency. The present chapter reports the same analyses described in Chapter 3 but including the BL, UH and UL bilinguals in addition to BH bilinguals and monolinguals. The two specific bilingual experiences, balanced usage of languages and proficiency of language (measured by English vocabulary), were expected to influence verbal and nonverbal task performances differentially.

In nonverbal task performance, balanced usage of both languages was expected to interact with English proficiency and contribute to the bilingual advantage observed in executive functions. Regardless of level of English proficiency, managing two language systems is essential to being bilingual. In the cognitive literature, improved performance on executive function tasks has been shown to be correlated with amount of cognitive training, especially in the patient populations (Levine, Robertson, Clare et al., 2000; Sammer, Reuter, Hullmann, Kaps and Vaitl, 2006). It is possible that the experience of managing two language systems mirrors the process of cognitive training and generates similar cognitive enhancement. Consequently, this cognitive training from bilingual experience enhances bilinguals' performance in nonverbal executive functions. If there is indeed such similarity, then balanced usage of two languages is predicted to play a more important role in nonverbal executive functions than proficiency in English. In other words, balanced usage of two languages in bilinguals is hypothesized to be the primary factor contributing to the positive force in cognitive control, with level of English proficiency being a secondary factor.

On this hypothesis, it would be interesting to examine how the opposing forces of bilingualism affect performance on a single task. In this study, the nonverbal tasks were designed to use a minimal level of linguistic processing. The stimuli in these tasks were symbolic and success did not rely on high language proficiency for completion. In contrast, the verbal tasks were chosen because they involve executive functions, specifically control of attention and linguistic processing. Eliciting both executive functions and linguistic processing in one task was expected to reveal how the opposing forces in bilinguals interact, i.e., advantage in cognitive control and disadvantage in linguistic representation. In this case, performance in the verbal tasks would allow direct examination of the influence of specific bilingual experience, i.e., balanced usage of two languages and level of English proficiency, on these opposing forces in bilingual research.

Previous research has shown that bilinguals' verbal performance was either similar to monolinguals (Gollan, Montoya, & Werner, 2002; Portocarrero, Burright, &

Donovick, 2006; Ransdell & Fischler, 1987) or at a disadvantage (Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Gollan, Montoya, & Werner, 2002; Ivanova & Costa, 2008). In some conditions of the verbal tasks used here, because both the positive and negative forces were involved, the general prediction was that bilinguals would perform similarly to their monolingual peers because these opposing forces would cancel each other out (positive force in executive functions, negative force in verbal proficiency). In such tasks, the level of balanced usage of two languages and of English proficiency could be used as tools to assess the relative contribution of each to verbal representation and executive functions. The specific hypothesis was that only bilinguals with levels of English proficiency comparable to monolinguals (the BH and UH groups) would benefit from bilingualism. In other words, high English proficiency would boost these bilinguals' processing to compensate for their weaker language representations. Balanced usage of two languages would further enhance these bilinguals' performance in a verbal executive function task.

Chapter 4 extended the results from the quantitative profiling of bilinguals in Chapter 2 and the performance differences between BH bilinguals and monolinguals in Chapter 3 by adding results from analyses described in Chapter 3 that include all four bilingual groups. The hypotheses were that balanced usage of two languages and English proficiency play an important role in nonverbal and verbal task performance respectively, but the contribution of each type of experience is not independent of the other so interactions between them are expected. In essence, specific bilingual experiences, i.e., balanced usage of two languages and language proficiency, were each expected to be responsible for one of the opposing forces, i.e., positive cognitive control and negative language representations respectively. In light of these hypotheses, the diverging nature of bilingual experience was expected to explain the contradictory results often found in bilingual research.

The results section of the present chapter reports statistics pertaining to each analysis conducted. The goal for statistical significance was severely limited by the unequal sample sizes and the low power resulting from the number of levels included in a between-group factor (five levels in the group factor). Therefore, this chapter focuses on the pattern of results, i.e., the ranking of group means, for the five bilingual subgroups and monolingual group on each dependent measure. Nonverbal task performance, measured by costs of response time relative to control trials, was expected to show an increasing trend from BH to monolinguals, with other bilingual (BL, UH and UL) groups falling in between. For verbal task conditions that only demanded language proficiency, the BH and UH bilinguals were expected to perform similarly to monolinguals, and the BL and UL bilinguals to show weaker performance. For verbal task conditions that required language proficiency and executive control, BH bilinguals were expected to have higher performance than UH bilinguals, because of the additional enhancement of executive functions resulting from balanced language usage. Monolinguals were expected to perform worse than the BH and UH bilinguals. For bilinguals with relatively lower English proficiency, namely the BL and UL groups, performance on verbal tasks requiring both language proficiency and executive control was predicted to be lower than other groups.

Method and Plan of Analysis

Participants were described in Chapter 2. The test battery and preprocessing of data and criteria were the same as that described in Chapter 3. The present GLM analyses incorporated the other three bilingual groups, increasing the number of groups to five (four bilingual groups and one monolingual group). Planned contrasts were set up as a priori multiple comparisons within GLMs instead of post hoc pairwise comparisons, in order to minimize the probability of type I error. These contrasts were: (1) all bilingual subgroups vs. monolingual (BH, BL, UH, UL vs. M); (2) Balanced usage bilinguals vs. monolingual (BH, BL vs. M); (3) High English proficiency vs. Monolingual (BH, UH vs. M); (4) Balanced vs. Unbalanced bilinguals (BH, BL vs. UH, UL); and (5) High vs. Low English proficiency bilinguals (BH, UH vs. BL, UL). The first contrast examined whether there was an overall difference between monolinguals and all bilinguals. The second and third contrasts assessed whether bilinguals with either balanced usage or high English proficiency performed differently than monolinguals. The fourth and fifth contrasts explored whether performance differed between levels within each specific bilingual experience. The bilingual subgroups were constructed along two non-independent continua (because factor scores of the two dimensions were continuous), so it was possible that group comparisons were affected by the relationship between these

Table 14. Summary of tasks and corresponding predictions for comparisons in performance between bilingual subgroups and monolingual group.

Task	Domain	Dependent variables	Prediction
Flanker Task	Nonverbal	RT and accuracy	BL, UH and UL bilingual subgroups would perform in between the BH bilinguals and monolinguals in terms of RT and cost analysis. No specific prediction could be made for BL, UH and UL bilingual subgroups.
Faces Task	Nonverbal	RT and accuracy	Prediction was similar to Flanker Task
Verbal Fluency	Verbal	Number of words	BH and UH bilinguals would perform similarly to monolinguals in category fluency. Other bilinguals would have lower performance. In letter fluency, the BH and UH bilinguals would produce more words than monolinguals. The BL and UL bilinguals' performance would either be lower or the same as monolinguals'.
Sentence judgment	Verbal	Proportion of positive judgment	BH bilinguals were expected to make more positive judgments for garden-path sentences because of the demand to dissociate grammaticality of the sentences from its ambiguous syntactic structures. However, the two groups would make similar proportions of judgment for the other types of sentences.

continua. Table 14 summarizes the experimental tasks and their corresponding predictions.

Results

Background tasks

Table 15 presents the descriptive statistics for the background tasks. Performance on the spatial subtests of WMS-III was analyzed in a two-factor Group (5) x Condition (2) GLM. Results showed that performance was slightly better in the backward condition, $F\ (1, 144) = 8.30$, $MSE = 4.26$, $p < .005$, $\eta_p^2 = 0.05$, with no difference between groups or interaction between group and condition, *F*s < 1.3, ns.

Cattell Culture Fair test performance was reported in age-corrected standardized scores. One-factor GLM showed a significant group difference, $F_{Welch}\ (4, 65.35) = 3.17$, $MSE = 226.16$, $p < .02$, $\eta_p^2 = 0.07$. The only significant contrast in the model was between the bilingual groups differing in level of English proficiency, $F\ (1, 143) = 7.97$, $p < .006$; bilinguals with high English proficiency scored higher than those with low English proficiency.

Table 15. Means and standard deviations of nonverbal background measures for all bilingual subgroups and monolinguals.

Background variable	**BH**[a] (n = 22)	**BL** (n = 29)	**UH** (n = 38)	**UL** (n = 21)	**M** (n = 40)
Forward Corsi	9.7 (2.9)	9.2 (2.3)	9.6 (2.4)	8.5 (2.8)	8.9 (2.7)
Backward Corsi	10.7 (2.7)	9.6 (2.9)	9.9 (2.7)	9.1 (3.0)	9.9 (2.8)
Cattell Culture Fair Test	117.0 (14.8)	106.7 (16.8)	110.4 (13.3)	104.0 (11.8)	113.3 (16.7)

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.

Nonverbal executive functions tasks

Chevron flanker task. Accuracy rates for all types of trials are presented in Table 16. No statistical analysis was conducted on accuracy rates because of the lack of variance caused by near ceiling values. With the high accuracy rates, differences in response time could not be attributed to speed-accuracy tradeoff.

Response times for all types of trials are presented in Table 17. Response times to control trials did not differ between groups, $F_{Welch}(4, 62.7) = 1.3$, ns. For the blocked condition, congruent and incongruent trials were submitted to a two-factor group by congruency GLM, which showed a strong congruency effect, $F(1, 135) = 374.4$, $MSE = 474.4$, $p < .0001$, partial $\eta^2 = 0.73$, but no effect for group, $F(4, 135) = 1.7$, ns., or group by congruency interaction, $F(4, 135) < 1$. Neutral trials in the neutral-nogo block also showed no significant group difference in a one-factor group GLM, $F_{Welch}(4, 59.7) < 1$.

Table 16. Accuracy rates for all types of trials in the Chevron flanker task.

Trial type	**BH**[a] (n = 22)	**BL** (n = 29)	**UH**[b] (n = 36)	**UL** (n = 21)	**M** (n = 40)
Blocked					
Control	0.98	0.99	0.99	1.00	0.98
Congruent	1.00	0.99	1.00	0.99	0.99
Incongruent	0.95	0.98	0.96	0.97	0.96
Neutral	0.99	1.00	1.00	1.00	0.99
Nogo	0.98	0.99	0.97	0.98	0.98
Mixed					
Congruent	1.00	0.99	1.00	0.98	1.00
Incongruent	0.97	0.97	0.96	0.96	0.97
Neutral	0.99	0.99	1.00	0.98	0.99
Nogo	0.94	0.92	0.93	0.93	0.92

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.
[b] Two participants' data from this group were excluded because of equipment failure.

For the mixed block condition, congruent, incongruent and neutral trials were analyzed in a two-factor group by trial GLM, which showed a marginally significant group difference, $F(4, 136) = 2.4$, $MSE = 19643.7$, $p < .06$, partial $\eta^2 = 0.06$, a strong trial effect, $F(2, 272) = 257.5$, $MSE = 1056.6$, $p < .0001$, partial $\eta^2 = 0.65$, and no interaction $F(8, 272) < 2.0$, *ns*. Planned contrasts of group means indicated that bilinguals with higher English proficiency performed faster than their bilingual peers with lower English proficiency, *F*s $(1, 136) > 5.8$, $p < .02$. Within-subject contrasts indicated that performance on the congruent trials was the fastest, followed by the neutral trials and then the incongruent trials. All comparisons between these trial types were significant, Fs $(1, 136) > 127.2$, $ps < .0001$.

Table 17. Mean response times (in ms) and standard errors for all types of trials in the Chevron flanker task.

Trial type	**BH**[a] (n = 22)	**BL** (n = 29)	**UH**[b] (n = 36)	**UL** (n = 21)	**M** (n = 40)
Blocked					
Control	399 (11)	421 (11)	405 (10)	422 (12)	397 (8)
Congruent	497 (14)	526 (16)	501 (12)	529 (15)	504 (10)
Incongruent	533 (10)	569 (11)	548 (11)	577 (14)	565 (11)
Neutral	553 (16)	587 (11)	570 (11)	579 (13)	565 (13)
Mixed					
Congruent	534 (16)	567 (13)	556 (14)	596 (19)	553 (14)
Incongruent	609 (14)	668 (16)	640 (15)	670 (19)	649 (16)
Neutral	571 (19)	638 (17)	602 (17)	641 (20)	601 (15)

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.
[b] Two participants' data from this group were excluded because of equipment failure.

As in Chapter 3, for the blocked condition, percentage change in response time for experimental relative to the control trials (i.e., relative cost) was also analyzed. These relative costs are shown in Figure 12. The flanker effect, namely the percentage increase in response time for incongruent relative to congruent trials in the blocked condition, is shown in Figure 13.

Figure 12. Flanker task, relative costs: Percentage increase in response times relative to control trials for blocked congruent, incongruent, and neutral trials.

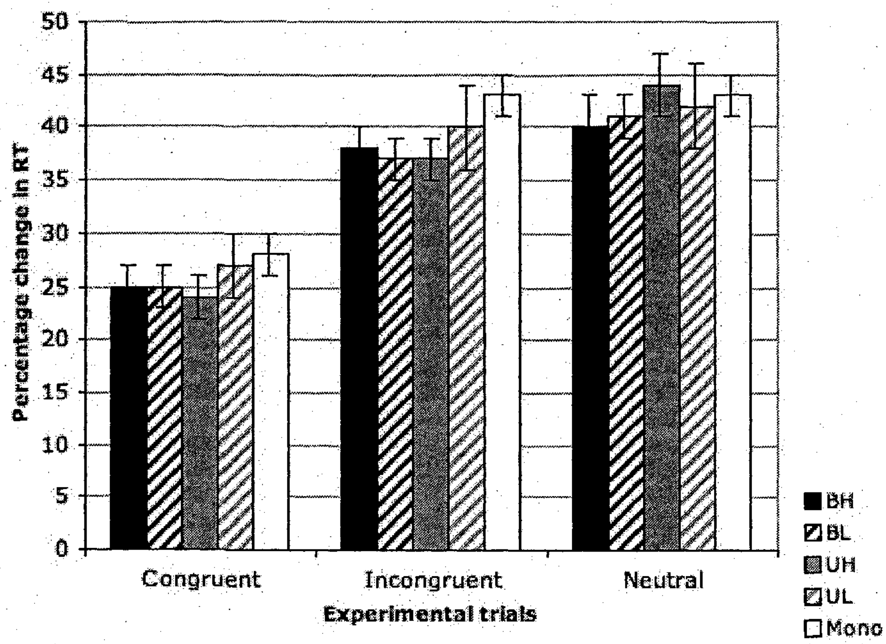
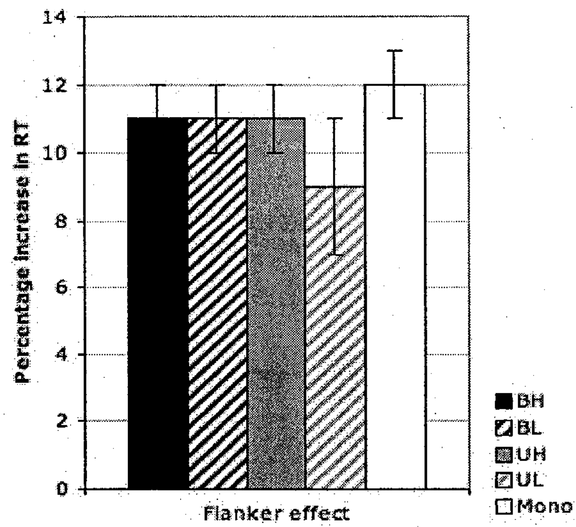


Figure 13. Flanker effect, relative costs: Percentage increase in response time for incongruent over congruent trials (blocked condition).

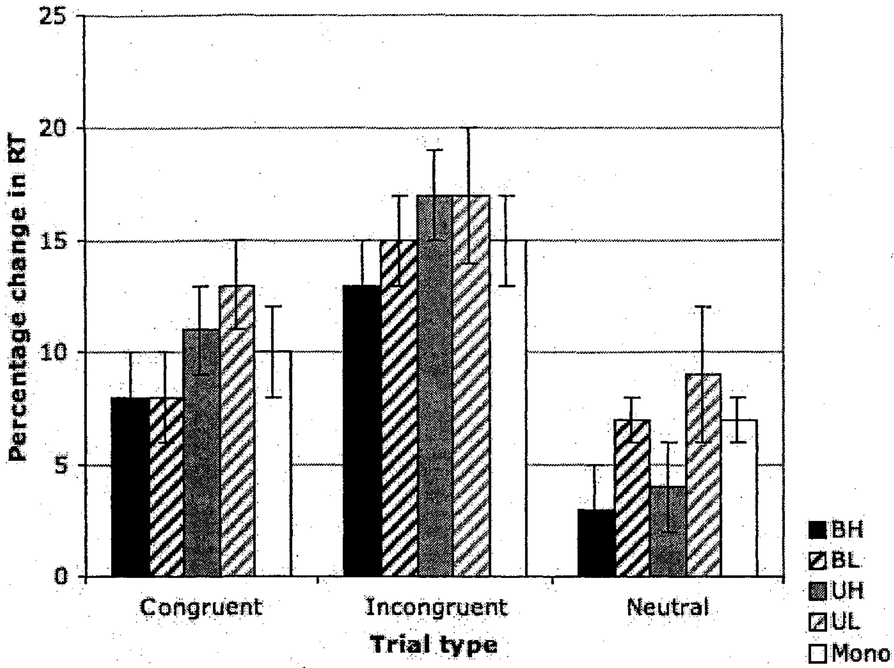


For percentage increase in experimental over control trials, no group difference was found for congruent and neutral trials, $Fs_{Welch} < 1$. Despite the significant difference between the BH bilinguals and the monolinguals in relative costs for incongruent trials reported in Chapter 3, no difference was found when the other groups of bilinguals were included in the analysis, $F_{Welch}(4, 58.3) = 2.0$, ns. Importantly, with a single exception (UH bilinguals, neutral condition), all bilingual groups had smaller relative costs than the monolinguals in all conditions. Furthermore, the BL, UH and UL bilinguals all fell in between BH bilinguals and monolinguals. For the flanker effect, all bilingual groups showed smaller costs than the monolingual group, but there was no significant group difference.

Mixing costs were calculated as the percentage change in response time for experimental trials in mixed relative to corresponding blocked trials. Mixing costs are presented in Figure 14. One-way GLM of language group found no group difference in mixing costs for congruent, incongruent and neutral trials, $Fs < 1.5$, ns. BH bilinguals nonetheless had smaller costs than all other bilingual groups and monolinguals. Interestingly, the monolinguals never showed the largest mixing costs.

From figures 12 and 13, the BH bilinguals generally suffered less in relative costs with the monolinguals suffering relatively more; the other bilingual groups formed an unsystematic pattern in between the BH bilinguals and monolinguals. The lack of systematic pattern between the middle three bilingual groups suggesting levels of different bilingual experiences contributed to the performance in nonverbal executive functions. The pattern of result was consistent with the hypotheses that balanced usage of languages and English proficiency interacted to provide gradation in bilingual advantage in a nonverbal task. Being high in either dimension alone did not lead to the full bilingual advantage as observed in the BH bilinguals. From Figure 14, the mixing costs showed a different pattern. The monolinguals did not always suffer the most compared to the bilinguals, although the bilingual groups formed an increasing trend with the balanced usage groups suffering smaller costs than the unbalanced groups (except for the neutral trials).

Figure 14. Flanker task, Mixing costs: Percentage increase in response time for congruent, incongruent and neutral trials in mixed relative to corresponding blocked trials.



Faces. Accuracy rates for the faces task are shown in Table 18. Accuracy rates were close to ceiling for all groups in all conditions, so no further analysis was conducted on the accuracy data. Raw response time data for the faces task are shown in Table 19. A one-factor GLM showed a significant group effect on mean response time for control trials (green eyes looking straight), $F_{Welch}(4, 62.1) = 3.9$, $MSE = 3506.2$, $p < .01$, partial $\eta^2 = 0.08$. Planned contrasts showed that monolinguals responded faster than all the bilingual groups.

Table 18. Faces task: Mean accuracy rates for all trial types task.

Trial type	**BH**[a] (n = 22)	**BL** (n = 29)	**UH** (n = 38)	**UL** (n = 21)	**M** (n = 40)
Blocked control					
Green eyes	1.00	0.98	1.00	0.99	0.98
Mixed Straight					
Green eyes	0.95	0.95	0.94	0.93	0.94
Red eyes	0.98	0.96	0.96	0.97	0.95
Mixed Gazes					
Green-Towards-asterisk	0.96	0.93	0.97	0.96	0.95
Red-Away-asterisk	0.96	0.95	0.94	0.94	0.96
Green-Away-asterisk	0.98	0.94	0.96	0.95	0.93
Red-Towards-asterisk	0.98	0.96	0.97	0.98	0.96

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.

In the mixed straight condition, trials with green eyes (respond to same side as asterisk) and red eyes (respond to opposite side from asterisk) were compared in a group x colour GLM. There was a significant colour effect, $F(1, 145) = 130.6$, $MSE = 595.2$, $p < .0001$, partial $\eta^2 = .47$, with slower response times for red vs. green eyes, but no effect for group or group by colour interaction, $Fs < 1.6$, ns. In the mixed gazes condition, the four types of trials were compared in a three-factor, group x colour x gaze direction GLM. Significant effects were found for colour, $F(1, 145) = 136.1$, $MSE = 1638.1$, $p < .0001$, partial $\eta^2 = .48$, gaze direction, $F(1, 145) = 34.32$, $MSE = 1481.1$, $p < .0001$, partial $\eta^2 = 0.19$, and colour by gaze interaction, $F(1, 145) = 5.01$, $MSE = 1026.1$, $p < .03$, partial $\eta^2 = .03$, but not for group, $Fs < 1.2$, ns. The interaction between colour and gaze showed that responses were faster on green trials when the eyes gazed towards versus away from the asterisk and faster on red trials when the eyes gazed away from versus towards the asterisk. In both cases, gaze indicated the correct response.

Table 19. Faces task: Mean response times (in ms) and standard errors for all trial types.

Trial type	**BH**[a] (n = 22)	**BL** (n = 29)	**UH** (n = 38)	**UL** (n = 21)	**M** (n = 40)
Blocked control					
Green eyes	189 (14)	189 (10)	170 (10)	192 (17)	147 (7)
Mixed Straight					
Green eyes	249 (27)	247 (19)	240 (18)	256 (29)	217 (17)
Red eyes	287 (27)	288 (20)	262 (18)	294 (28)	245 (16)
Mixed Gazes					
Green-Towards-asterisk	263 (32)	267 (21)	238 (17)	281 (27)	224 (18)
Red-Away-asterisk	322 (32)	331 (22)	296 (19)	340 (30)	280 (17)
Green-Away-asterisk	276 (31)	290 (24)	268 (22)	312 (32)	254 (21)
Red-Towards-asterisk	319 (31)	314 (23)	281 (20)	326 (31)	264 (17)

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.

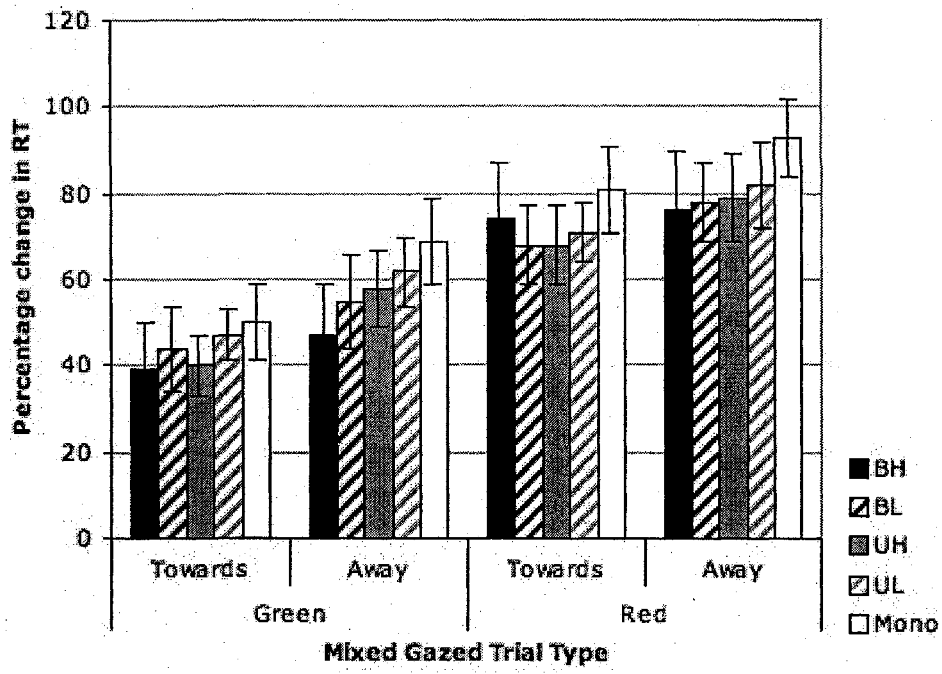
As in Chapter 3, percentage change in response times were calculated for the four types of trials in the mixed gaze condition by subtracting response time in the blocked control trials (green eyes looking straight) from response time in the mixed gaze trials. These relative change percentages are presented in Figure 15. The group x colour x gaze analysis was repeated for these percentage increases. Similar to findings with response times as dependent variables, this analysis showed robust colour and gaze main effects, *Fs* > 8.3, *ps* < .006, but no effects for group, $F(4, 143) < 1$, two-way interactions, *Fs* < 2.5, *ns*, or three-way interactions, $F(1,143) < 1$.

In Figure 15, an increasing trend in the percentage increase in RT relative to control trials was suggested within the bilingual groups and from bilinguals to monolinguals in two costs. This pattern was only apparent in Green Away and Red Away costs of the mixed gaze conditions. The pattern of the BH bilinguals suffering least in percentage increase and monolinguals suffering the most shown in the flanker task was replicated in a different nonverbal task. Moreover, the other bilingual groups (BL, UH and UL) all lined up between the two groups with the most contrasting language experience in the more difficult conditions (the away conditions) that associated with green or red eyes.

Verbal executive functions tasks

Verbal fluency. Means and standard deviations for verbal fluency performance scores are reported in Table 20. One-factor GLMs for group were used to analyze these scores. In the letter tasks, there was a significant group difference in all three conditions, $F_{Welch} > 5.0$, *ps* < .002. Planned contrasts showed that for all conditions in the letter task,

Figure 15. Faces task: Relative costs of experimental versus blocked control trials (green eye looking straight) by colour and by gaze direction.



high proficiency bilinguals outperformed monolinguals and low proficiency bilinguals, *Fs* > 6.6, *ps* < .02. For producing words in the clothing category, the only significant difference was between the high and low English proficiency bilinguals, with high proficiency bilinguals scoring higher, $F(1, 141) = 24.6, p < .0001$. For word production in the girls' names category, all bilinguals produced fewer items than monolinguals, $F(1, 141) = 5.9, p < .02$, bilinguals with balanced usage of languages produced fewer names than their peers with unbalanced usage, $F(1, 141) = 6.4, p < .02$, possibly due to the lower performance of the BL bilinguals.

Standardized scores controlling for age were computed for letter and category tasks separately. These scores are shown in Figure 16. Significant group effects were observed in standard scores for both letter, F_{Welch}(4, 63.7) = 9.6, *MSE* = 10.5, $p < .0001$, partial $\eta^2 = .21$, and category tasks, F_{Welch} (4, 62.6) = 6.9, *MSE* = 10.8, $p < .0002$, partial $\eta^2 = .14$. Planned contrasts for the letter tasks showed that bilinguals with high English vocabulary produced more words than monolinguals and bilinguals with low English vocabulary. A different contrast pattern was observed in the category task: bilinguals with high English vocabulary performed similarly to monolinguals, and the group difference was driven by the lower performance in the bilinguals who had lower English vocabulary.

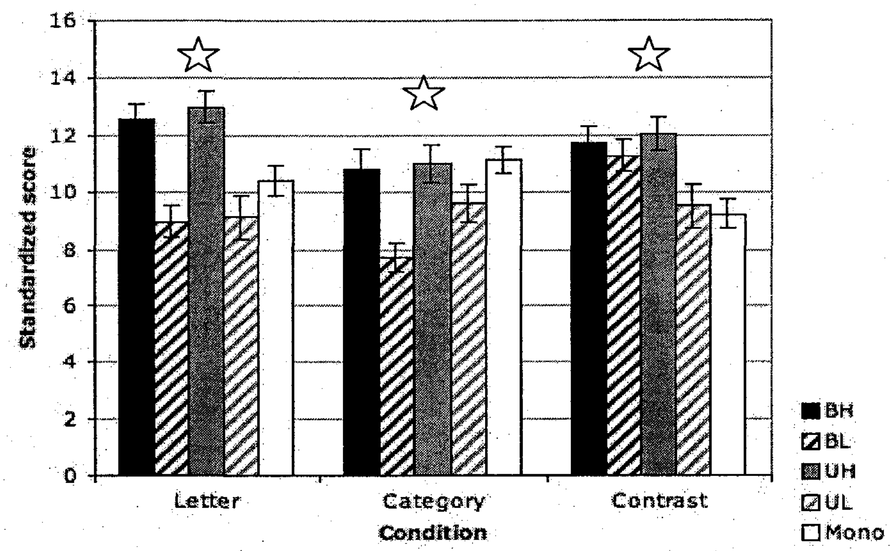
Table 20. Mean number of correct responses and standard deviations for all conditions in verbal fluency task

Condition	**BH**[a] (n = 22)	**BL** (n = 29)	**UH** (n = 36)	**UL**[b] (n = 20)	**M**[b] (n = 39)
Letter	44.4 (8.4)	32.4 (9.8)	46.0 (12.2)	33.7 (12.0)	37.2 (10.6)
F	15.4 (3.0)	10.8 (3.5)	14.8 (5.1)	10.9 (4.3)	12.6 (4.4)
A	12.3 (3.4)	8.9 (4.2)	13.6 (5.0)	10.3 (4.5)	10.6 (4.2)
S	16.8 (4.6)	12.7 (3.9)	17.5 (3.7)	12.5 (4.5)	13.9 (3.5)
Category	39.6 (9.1)	32.0 (6.6)	40.4 (10.2)	36.4 (7.6)	40.7 (7.6)
Clothing item	18.5 (4.7)	14.3 (4.5)	18.7 (4.8)	13.9 (4.0)	17.5 (4.5)
Girl's name	21.2 (6.0)	17.7 (3.9)	21.7 (6.5)	22.5 (5.0)	23.2 (4.6)

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.

[b] Two subjects' data could not be collected due to equipment failure.

Figure 16. Standardized scores of letter fluency, category fluency and primary contrast.



* Star indicated significant GLM model at $p < .01$.

According to the D-KEFS' examiner's manual (Delis, Kaplan, & Kramer, 2001), letter and category fluency tasks demand different sets of skills. Therefore, performance between these two tasks was compared. The letter task requires both proficiency of language and executive functions. The activity involved was phonemic retrieval and the output items are restricted by different criteria (e.g., no numbers, no names, no places). The category task requires primarily proficiency of language but little executive function because there is no restriction on production and semantic retrieval is an overlearned task. However, a direct comparison may not be accurate because letter and category tasks had different numbers of conditions (three letters, two categories). Therefore, the time involved in the letter task (three minutes) was longer than the time involved in the category task (two minutes). When performance from both tasks was transformed to standardized scores, a direct comparison was possible.

The manual of Delis-Kaplan Executive Functions Systems recommends using primary contrast scores to compare performance between letter and category tasks (Delis, Kaplan, & Kramer, 2001). Primary contrasts are obtained by transforming the scaled difference between letter and category tasks (letter standardized score – category standardized score) to another set of standardized scores. The standardized differences are designed to measure the magnitude of disproportionate performance in letter and category fluency. Based on the standardized scores for the letter and category raw scores, the standardized mean of the primary contrast is 10, which indicates no difference between letter and category fluency. A primary contrast score of less than 10 indicates lower performance in letter than category tasks, and a score greater than 10 indicates higher performance in letter tasks. In addition, better performance in the letter task indicates higher level of executive functions. A one-factor (group) GLM on primary contrast scores showed a significant group effect, $F_{Welch}(4, 63.8) = 5.0$, $MSE = 10.4$, $p < .002$, partial $\eta^2 = 0.13$. All contrasts were significant, $Fs\ (1, 141) > 5.2$, $p < .03$, except for the contrast between bilinguals with high and low balanced usage of languages, $F\ (1, 141) = 1.1$, ns. Overall, except for UL bilinguals, all bilinguals had higher primary contrast scores than monolinguals indicating higher levels of executive control. This pattern of results indicates that the bilinguals with high levels of English proficiency performed better in letter than in category fluency. Furthermore, BL bilinguals were at the same level as the BH and UH bilinguals despite their low English proficiency. In other words, the BH, UH and BL bilinguals had better performance in letter tasks than in category tasks while the UL bilinguals and monolinguals performed similarly in both fluency tasks.

Sentence grammaticality judgment task. Descriptive statistics for the percentage judging the presented sentences as grammatically correct are shown in Table 21. A significant group effect was observed in judging as correct sentences that were non-garden-path grammatical, $F_{Welch}(4, 60.2) = 2.7$, $MSE = .02$, $p < .04$, partial $\eta^2 = 0.07$, and non-garden-path ungrammatical, $F_{Welch}(4, 58.7) = 7.4$, $MSE = .02$, $p < .0001$, partial $\eta^2 = 0.18$. For non-garden-path grammatical sentences, the only significant contrast was between the two English proficiency level of the bilinguals, $F(1, 143) = 9.6$, $p < .003$. For the non-garden-path ungrammatical sentences, all the bilingual groups made more incorrect judgments than monolinguals, $F(1, 143) = 10.2$, $p < .002$, with the bilinguals having low English proficiency being especially poor, $F(1, 143) = 20.9$, $p < .0001$. There was no group difference between groups in the judgments of the garden-path sentences.

Discussion

The present study followed up the bilingual profiles established in Chapter 2 and the bilingual performance differences found in Chapter 3 by examining the divergent influences of different bilingual experiences on cognition. Together with monolinguals, bilinguals with varying levels of language usage and English proficiency were given a

Table 21. Mean and standard deviation of percentage of judgments for presented sentences as grammatically correct.

Type of Sentences	BH[a] (n = 22)	BL (n = 29)	UH (n = 38)	UL (n = 20)	M[b] (n = 39)
Garden-path (GP)	66 (14)	66 (15)	67 (12)	65 (21)	64 (13)
Non-GP grammatical	91 (9)	80 (15)	88 (9)	83 (22)	86 (10)
Non-GP ungrammatical	12 (13)	25 (15)	10 (14)	23 (22)	9 (8)
Nonsense	7 (9)	17 (21)	8 (13)	15 (23)	9 (8)

[a] Subgroup abbreviations: BH = Balanced bilingual/High English vocabulary; BL = Balanced bilingual/Low English vocabulary; UH = Unbalanced bilingual/High English vocabulary; UL = Unbalanced bilingual/Low English vocabulary; M = Monolingual.
[b] One participant failed to complete the task.

battery of tasks measuring nonverbal reasoning, spatial memory, and executive functions in verbal and nonverbal domains. Overall, two findings were noted for the bilingual subgroups in response time costs in nonverbal executive functions tasks. First, in all the analyses, balanced bilinguals with the highest level of English proficiency showed the smallest costs when faced with interference, although this difference did not always reach statistical significance when compared to monolinguals. As mentioned previously, the lack of statistical significance in the present chapter possibly reflected the low power associated with unequal sample sizes and five levels in a factor. Second, the other bilingual subgroups, namely the BL, UH and UL bilinguals, generally showed intermediary performance between the BH bilinguals and monolinguals. This pattern of results was shown in both the flanker task and the faces task. In verbal production that required executive functions, bilinguals with a high level of English proficiency performed significantly better than monolinguals. The role of proficiency was also apparent in sentence grammaticality judgment: the bilinguals with lower proficiency in English tended to accept more ungrammatical non-garden path sentences and nonsense sentences as correct. Therefore, bilingual usage did not affect syntactic judgment of transitively-biased sentences, but language proficiency did.

Nonverbal executive functions

The bilingual advantage was observed in the nonverbal executive functioning tasks (flanker and faces tasks), mostly between the BH bilinguals and monolinguals, which formed the two extremes in terms of language experience. Results from the present study largely replicate previous research showing small, often statistically non-significant, bilingual advantage in response time tasks in young adults (e.g., Bialystok, Craik, & Ryan, 2006), although a few statistically significant results were reported in Chapter 3 between the two most contrasting groups. Overall, bilingual participants often had smaller costs in response time than monolinguals, indicating that they suffered less in conditions that required resolution of conflicting stimuli. The young adults who served as participants were at their highest functioning stage in lifespan; therefore, it is possible that any systematic group differences were diminished because all the participants were performing at their highest level. Despite the high-functioning age group, a consistent pattern was that the BH bilinguals showed least amount of costs in response time, with the monolinguals often showing the largest costs and other bilingual subgroups, BH, BL, UH and UL bilinguals, being in between, with no systematic rank order between these bilingual subgroups.

The chevron flanker task was intended to examine participants' ability to suppress interference (in the blocked congruent-incongruent condition) and inhibit behavioural response (in blocked neutral-nogo condition) and their response flexibility (in the mixed condition). Collectively, in the two-group comparisons from Chapter 3 (BH bilinguals vs. Monolinguals), the BH bilinguals performed better in suppressing interference (lower percentage increase in response time to incongruent relative to control trials), and in responding flexibly (lower percentage increase in response time to neutral trials in the mixed condition relative to neutral trials in the blocked condition). There was no group difference in the accuracy rates of nogo trials, indicating that bilingualism did not affect behavioural response inhibition. Instead, bilinguals in general suffered less when encountering interference (Incongruent trials) or more competing alternatives (Mixing trials). In solving both types of trials, selective attention was necessary. In face of interference, selective attention was required to focus on the target while ignoring the flankers. Similarly, in the mixed condition, selective attention was needed to determine a response rule. When other bilingual subgroups were included in the comparisons, their levels of costs were often in between the BH bilinguals and monolinguals. This suggests that partial bilingual experience could also enhance performance in nonverbal executive functions tasks, although specific bilingual experience seems to have different influences on different types of costs.

The faces task, unlike the chevron flanker task, demanded a set of different processes as discussed in Chapter 3. The series of events presented in the faces task required the coordination of obeying two opposing rules in response to a very subtle fast-appearing stimulus. In the gaze conditions, participants' decision to make a response was facilitated or interfered with by the different gazing directions of the faces' eyes. The pattern of results analyzing the costs in response time in the gaze relative to baseline response time in the same task context was similar to that observed in the flanker task: The bilingual subgroups had lower response time costs compared to the monolinguals, with the BH bilinguals having the smallest costs.

In regard to the contribution of specific bilingual experiences on cognition, the proposal was first established by showing the difference between the BH bilinguals and the monolinguals in Chapter 3. Then, Chapter 4 repeated the analyses by including bilinguals with different levels of experience in balanced usage of languages and proficiency. Strikingly, the costs analysis in both chevron flanker and faces tasks revealed a similar pattern: smallest costs for BH bilinguals and largest costs for monolinguals, with other bilingual subgroups typically falling in between. The two bilingual experiences interacted and formed different patterns in the cost analyses for the flanker and faces tasks. From this observation, it was interpreted that being high in balanced usage between languages and being high in English proficiency combined to result in the largest enhancements in performing nonverbal executive functions tasks. In comparison to the bilingual participants in Costa, Hernández, and Sebastián-Gallés

(2008), the participants recruited for this dissertation in Toronto had much more diverse and heterogeneous language backgrounds. The bilingual participants in Costa, Hernández, and Sebastián-Gallés' study (2008) were homogeneous in that they were all simultaneous Spanish-Catalan bilinguals. According to Costa, Hernández, and Sebastián-Gallés (2008), these participants were both highly balanced in functional usage of Spanish and Catalan as well as attaining high levels of proficiency in both languages, which was similar to the characteristics of the BH bilinguals in the present study. Therefore, while the recruitment of bilinguals with diverse language experience allowed the examination of a more dynamic contribution of bilingualism, the data became increasingly heterogeneous.

Verbal executive functions tasks

The two verbal executive functions tasks revealed a somewhat different pattern of results. In verbal fluency tasks, the letter and category fluency conditions demanded different skills to perform successfully. While both fluency tasks required lexical retrieval, letter fluency performance also relied on executive control. Bilinguals have usually been shown to have lower performance in lexical retrieval (for lower number of retrieval items: Gollan, Montoya, & Werner, 2002; for slower retrieval time: Ivanova & Costa, 2008) but higher performance in executive functions (e.g., Bialystok, Craik, et al., 2004; Bialystok, Craik, & Ryan, 2006). For bilinguals with similar levels of English vocabulary as the monolinguals, they produced more correct items than the monolinguals in the letter fluency task (which required executive functions and English proficiency), but performed similarly to monolinguals in category fluency (which relied heavily on English proficiency). In a task that reflected both opposing forces, the results suggest that English proficiency is a stepping-stone for bilinguals to achieve higher performance than monolinguals. When the bilinguals were grouped together regardless of their subgroup affiliation, there was no significant difference between language groups in the letter task (for bilinguals, $M = 39.6$, $s.d. = 12.4$; for monolinguals, $M = 37.6$, $s.d. = 10.8$), $F(1, 146) < 1$, but a significant bilingual disadvantage in category fluency (for bilinguals, $M = 37.2$, $s.d. = 9.2$; for monolinguals, $M = 40.7$, $s.d. = 7.5$), $F(1, 146) = 4.6$, $MSE = 76.6$, $p < .04$. This pattern of results replicates previous research (Gollan, Montoya, & Werner, 2002; Portocarrero, Burright, & Donovick, 2007; Rosselli, Ardila, et al., 2000) showing an unreliable monolingual-bilingual difference in letter fluency, but a bilingual disadvantage in category fluency. It also suggests that previous research that did not segregate bilinguals by these two bilingual experiences had in fact ignored an important confounding factor.

By comparing bilingual subgroups in verbal fluency against monolinguals, the two dimensions of bilingualism were apparent. Fluent verbal production required language proficiency. Previous research has found that bilinguals generally had a lower level of language proficiency, even in their dominant or first language (e.g., Portocarrero, Burright, & Donovick, 2007). Therefore, without properly controlling for proficiency in monolinguals and bilinguals, bilinguals' lower performance in verbal tasks cannot be concluded to be solely due to the experience of managing two languages. A lower vocabulary level could also contribute to low performance in verbal tasks. Therefore, it is important to control for proficiency before attributing any group difference to bilingualism.

In the sentence grammaticality judgment task, all participants regardless of their language experience, judged the grammaticality of the sentences to a similar level (approximate proportion of judging the sentences to be correct was .66 when sentences were mixed with different predicate types and grammaticality), which was consistent with previous research (Osterhout, Holcomb, & Swinney, 1994). Syntactic judgment of garden-path sentences was related to working memory (Kemper, Crow, & Kemtes, 2004), and often resulted in misinterpretation of the meaning of the sentence (Ferreira, Christianson, & Hollingworth, 2001). For the purpose of the present experiment, participants were asked to judge the grammaticality of the sentence. The proposal was that bilinguals with higher English proficiency would be better at ignoring one aspect of the sentences (the ambiguous syntactic information) while paying attention to a competing dimension (grammaticality). Grammaticality judgment was chosen as target because it was subtler than semantic information and should elicit difference in accuracy rates between language groups. However, regardless of bilinguals' balanced usage, all participants judged similarly. This pattern of results could be a consequence of (1) the short amount of time allowed to process the sentences; and (2) heterogeneity of the set of grammatical non-garden path sentences (Flagg, personal communication). It was noted that half of the grammatical non-garden path sentences differed in whether *that* was included before introducing the complement clause. This manipulation created sentences that were similar to the garden-path sentences with transitively-biased verbs. As a result, the non-ceiling judgments (even for the monolinguals and highly proficient bilinguals) were observed in the grammatical control sentences. However, participants with lower level of English proficiency were more likely to accept ungrammatical or nonsense sentences as correct. This suggests that participants with lower level of English proficiency were not as sensitive to sentence grammaticality. Perhaps, the influence of bilingualism may not extend to the sentence-level processing which requires syntactic understanding.

Overall, the two dimensions identified in Chapter 2, namely balance in usage of languages and English vocabulary level, had differential effects on verbal and nonverbal tasks. In regard to the opposing forces that resulted in divergent consequences in bilingualism, balanced usage of languages and language proficiency interacted to affect results in nonverbal tasks, but language proficiency provided a criterial level for bilinguals to outperform monolinguals in verbal tasks. Furthermore, BH bilinguals and the monolinguals formed two extremes on the comparisons of response time cost, with other bilingual subgroups showing intermediary performance between the BH bilinguals and monolinguals. In terms of verbal tasks, while confirming previous research that bilinguals had lower performance in verbal production, balanced usage of language and language proficiency modulated performance in verbal fluency. With a similar level of English proficiency, bilinguals' performance in verbal executive functions was shown to be better than their monolingual peers. Therefore, it appears that bilinguals who have achieved a high level of language proficiency receive additional enhancement in a verbal executive functions task. In summary, balanced usage of languages and language proficiency provided general enhancements to bilinguals' performance in nonverbal tasks, while language proficiency became the stepping-stone for these bilinguals to achieve in verbal tasks.

Chapter 5. General Discussion

This dissertation explored the basis of conflicting results from bilingual research: in nonverbal executive functions tasks, bilinguals often outperform monolinguals but in verbal tasks, bilinguals often show no difference or perform more poorly than monolinguals. It was suggested that viewing bilingualism as a unified construct could not explain these conflicting patterns of results. If bilingualism were dynamic and multi-faceted, however, then different aspects of the experience might lead to positive and negative outcomes. Unlike previous research attributing different patterns of results to bilingualism as a whole, the present dissertation shows that different bilingual experiences have different contributions to performance on verbal tasks and nonverbal executive function tasks. Understanding the nature of these bilingual experiences is important to gaining insights into how bilingualism influences cognition.

Three significant findings emerged from the dissertation: (1) there were related but separable bilingual experiences, namely balanced usage of languages and English proficiency (as measured by vocabulary level); (2) bilinguals enjoyed cognitive benefits in nonverbal tasks and suffered from weaker language representations at the same time; and (3) for nonverbal task performance, high level of balanced usage and high English proficiency always led to the greatest performance advantage over monolinguals, with lower levels of balanced usage and proficiency leading to more modest enhancements or even disadvantages compared to monolinguals in some conditions. For verbal task performance, English proficiency was shown to be the primary contributing factor. In summary, findings showed bilingualism to be a multi-faceted phenomenon with different influences on verbal and nonverbal tasks. Moreover, different bilingual experiences have different levels of effect on verbal versus nonverbal performance. The three findings are addressed below in light of the results reported in this dissertation and current findings in bilingual research.

Dimensions of Bilingual Experience

In the review of four psycholinguistic models, it was proposed that RHM and the weaker links hypothesis focus on the effects of bilingualism on language proficiency while ICM and BIA+ primarily concern how bilinguals manage two language systems under the control of language-general cognitive mechanisms. Based on that interpretation, the factor analysis reported in Chapter 2 extracted two dimensions of bilingualism.

The first dimension, balanced usage of two languages, was experience-based and was suggested to interact with the second dimension to produce positive effects on executive function tasks. The usage dimension was derived from the cognitive control aspects of ICM and BIA+. With the dominant communicating language in Toronto being English, bilingual participants in this study reported very high usage of English outside of their homes and varying usage of non-English languages at home. The balanced usage of languages in the present dissertation then concerned *how much* non-English language a bilingual used on a daily basis at a home setting in an English-speaking community.

The second dimension, proficiency of English, was skill-based and proposed to be the source of negative consequences for bilinguals' verbal performance. This dimension was related to the two bilingual models that emphasize proficiency of language, namely the RHM and weaker links hypothesis. Proficiency of English, measured as both receptive and expressive English vocabulary skills, represents *how proficient* a bilingual is in lexical knowledge. As expected, both experiences being part of bilingualism, the two dimensions were related to a moderate extent. Therefore, these two dimensions were expected to contribute jointly to task performance.

Bilingual research in the past has largely focused on examining the influence of bilingualism on different types of task performance, for example, comparing the performance of monolinguals and bilinguals on verbal or nonverbal tasks. Differences in performance were then attributed to bilingualism without differentiating the influence of specific bilingual experiences to those overall results (e.g., for bilingual advantage, e.g., see Bialystok & Shapero, 2005; Costa, Hernández, & Sabastián-Gallés, 2008; for bilingual disadvantage, e.g., see Ivanova & Costa, 2008; Gollan, Fennema-Notestine, Montoya, & Jernigan, 2007). In fact, one published study was conducted to examine the "components" of bilingualism empirically, as part of the bilingual questionnaire development (LEAP-Q).

The first two factors reported by Marian, Blumenfeld and Kaushanskaya (2007) (MBK) are similar to the two bilingual dimensions extracted here (see chapter 2), despite MBK's small sample size and their assumption that these factors were uncorrelated. MBK's "Relative L2-L1 competence" factor is similar to the balanced usage factor identified in the present study: both include variables that addressed the degree of interaction between L1 and L2 in daily life. Furthermore, the "Relative L2-L1 competence" factor is based on a mixture of L1 and L2 variables so it also incorporates aspects of the balanced usage factor that include English and non-English language on the extremes of response scales. Unlike the usage LSBQ scales used in the present study, however, items in the LEAP-Q questionnaire that MBK used were unidimensional and only measured characteristics of one language at a time: every L1 variable was paired with an L2 variable measuring the same constructs, e.g., L1 exposure to reading had a parallel variable for L2 exposure to reading. Despite the subtle instrumental differences, MBK's "Relative L2-L1 competence" factor and this study's balanced usage factor are similar in their defining variables.

MBK's "L1 learning" factor was related to proficiency or fluency level of L1. About one third of their sample reported Spanish as L1 and the rest reported English as L1. In the present study, only English vocabulary was measured. The proportions of bilinguals reporting English as L1 and English as L2 were approximately the same, 48% vs. 51% respectively. Therefore, the English vocabulary factor reported in the present dissertation reflected either L1 or L2 proficiency skills.

The major difference between the designs used by Marian, Blumenfeld, and Kaushanskaya (2007) and the present study is that language usage for English and non-English languages was defined as two extremes on the same continuum in the present study and participants were asked to judge the proportion of usage between the two languages. Unlike the MBK's approach to separate L1-L2 status, the present study did not adopt that approach because L1-L2 status may not mirror language dominance and language dominance may change depending on different contexts. Although Marian, Blumenfeld and Kaushanskaya (2007) asked participants to report their dominant language(s) in addition to languages acquired in chronological order, the language dominance data were not included in analyses. Instead, order of language acquisition was taken as the criterion to segregate the stronger from the weaker language. The present study avoided the debate on language acquisition and language dominance and only measured language proficiency in the most common languages used by its particular bilingual participants. While the MBK study focused on characteristics of bilingualism in terms of L1 and L2, the present study emphasized the relative usage between the languages and not the sequence in which they were acquired.

Other features of the bilingual experience might possibly interact with balanced usage and language proficiency. One such feature is how long one has been bilingual. This feature was explored as part of the bilingual history reported in chapter 2. Age of L2 acquisition was measured to determine both formal and informal language acquisition experience. Formal and informal age of L2 acquisition were defined, respectively, as the age at which L2 was studied in a school setting and the age of acquiring L2 at home informally. These two age of acquisition measures have been commonly used in bilingual research (Mechelli, et al., 2004; Perani, Abutalebi, Paulesu, Brambati, Scifo, Cappa, & Fazio, 2003; Wartenburger, Heekeren, Abutalebi, Cappa, Villringer, & Perani, 2003). The LSBQ used in the present dissertation included an additional measure of bilingual history, the age of starting to *use* the two languages actively on a daily basis. This measure was called the age of active bilingualism. Compared to balanced usage of languages, which measured degree of balanced usage on a daily basis, the difference between age in years and age of active bilingualism indicated the length of active bilingual experience. Similarly, formal and informal age of acquisition was subtracted from age in years to obtain formal and informal length of L2 acquisition.

Additional analyses were run to assess the role of these three variables to bilingual advantages/disadvantages in verbal and nonverbal tasks. To examine whether the length of active bilingualism is related to the bilingual advantage observed in the nonverbal executive functioning tasks, a correlation was calculated between length of active bilingualism and mixing cost in response time for the neutral trials (RT for mixed neutral trials – RT for blocked neutral trials) in the flanker task. The analysis showed a significant negative relation between these two variables, $r\ (94) = -.32, p < .002$, suggesting longer length of active bilingualism was related to smaller mixing costs for neutral trials. There was no significant correlation between other costs and the length of active bilingualism, formal and informal length of acquisition. For the faces task, the costs for conditions with eyes gazing towards the asterisk for green and red eyes correlated negatively with both formal and informal length of L2 acquisition, $r\text{s}\ (109) > -.20, p\text{s} < .04$, with no correlation between length of active bilingualism and any of the costs in the faces task. For verbal tasks, letter fluency performance was positively correlated with length of active bilingualism, $r\ (100) = .26, p < .01$, indicating that being an active bilingual longer was related to better performance in letter fluency. No other correlation between verbal performance and length of acquisition was significant.

These reported correlations indicated that there might be additional bilingual experiences that might contribute to bilinguals' different performance in verbal and nonverbal tasks when compared to monolinguals. Moreover, these additional bilingual experiences could be more apparent in a bilingual population with a large age range. Therefore, while this study confirmed the existence of the two dimensions to define bilingual experience, namely balanced usage of languages and English proficiency, in a Canadian sample of university students, further research is needed to establish if these two dimensions are sufficient to define the experience of other populations. For example, studying a population with a larger age range, the length of being an active bilingual could be investigated along with the daily balanced usage and language proficiency. In addition, verifying if these two bilingual dimensions in different cultural populations, e.g., European or Asian, would provide insights into the generalizability of these bilingual dimensions and extend the implications to populations outside North America. It is expected that similar factors would emerge in bilinguals from other populations, but this finding could be limited by different cultural contexts. For example, in European countries, it is common for an individual to be fluent in multiple languages; but in other countries, learning a second language is limited to certain sub-populations, e.g., only certain social classes are given the opportunity to learn English in India.

The speculation that similar factors would still be extracted is based on the fact that factor scores obtained in factor analysis were from a standardized distribution with the mean as zero. Therefore, responses from all participants were scores relative to other responses within the sample, i.e., scores used to construct these bilingual dimensions are not absolute but represent the whole sample's responses along a continuum for each dimension. So, regardless of the population, continua with a similar factor pattern are expected. In other populations, it may be beneficial to compute a relative usage score which is essentially a proportion of balanced usage at home and outside of the home. In Toronto, English is the dominant communicating language and all participants in this study attended an English-speaking university, so home language usage scores were used; they were unlikely to deviate much from relative usage scores because both are based on the dominant usage of English outside of homes. Similarly, it would be interesting to investigate the relative proficiency in both languages if a sufficiently large sample could be recruited. Then, both usage and proficiency factors could be defined in terms of language relativity. The luxury of testing a homogeneous sample of bilinguals with similar languages was not possible in the present study. Future studies could replicate the design in chapter 2 but add extra language proficiency measures that were co-normed with PPVT-III and EVT in different languages, such as French and Spanish.

Another logical extension of this research is that having established two dimensions that characterize bilingual experience, it is now important to determine the precise influence of other bilingual experiences on cognitive and linguistic outcomes. Other than cross-linguistic research that may only involve bilinguals, other psycholinguistic studies often compare monolinguals to bilinguals in order to examine if the experience of handling two languages generates any difference in performance on a variety of tasks. Aside from their language experiences, monolinguals and bilinguals are often matched in background measures such as age, education, social economic status, and other characteristics. As a result, any difference in performance found between monolinguals and bilinguals can be attributed to bilingualism. Future research could link performance differences to one or more of the specific bilingual experiences rather than to bilingualism globally, and/or identify additional bilingual experience that may affect language and cognition.

The opposing forces

Bilingual research often reports divergent results for monolinguals and bilinguals in both verbal and nonverbal tasks, with a bilingual advantage over monolingual peers typically reported in tasks that require control of attention. These nonverbal tasks measure different aspects of executive functions. One commonality among them is that responses for these tasks do not require language, e.g., responding to the colour of a stimulus by pressing left or right keys (Bialystok, et al., 2004) or responding to the direction of a target arrow while ignoring distracters (Costa et al., 2008). In contrast, bilinguals perform more poorly than monolinguals in verbal tasks, such as verbal fluency (e.g., Gollan, et al., 2002) and lexical retrieval (e.g., Gollan & Silverberg, 2001; Gollan et al., 2007). Despite the direction of performance differences in verbal and nonverbal tasks, both are consequences of bilingualism. Being a bilingual is similar to being pulled by two opposing forces: while the practice of managing two languages gives rise to cognitive advantages, the burden of the same experience leads to weaker language representations.

Chapter 3 examined the effect of the opposing forces of bilingualism. The bilingual subgroup with high levels of balanced usage and high English proficiency (BH) was compared with a monolingual control group on verbal and nonverbal tasks. The bilingual advantage in nonverbal executive functions found in previous research was replicated: BH bilinguals suffered less than monolinguals in conditions that required suppressing distraction or resolving conflict. In verbal tasks, there was only a group difference in lexical retrieval performance (i.e., letter and category fluency), but the difference did not extend to the sentence processing level. Contrary to the usual pattern, these high proficiency and high usage bilinguals performed better than monolinguals in letter fluency, despite their similar performance in category fluency. Their similar performance in category fluency indicated their matched level of English proficiency. In letter fluency, the BH bilinguals had extra benefits because of task demands: in addition to language proficiency, letter fluency also requires executive control because of the restrictions and the demand in phonemic retrieval. In other words, the letter fluency task requires both the positive and negative forces of bilingualism. When the negative force (weaker language representation) is accounted for, the positive force (enhanced executive control) becomes apparent.

At the sentence-processing level, no difference was found between all bilingual groups and monolingual controls when asked to judge the grammaticality of sentences. The focus of previous bilingual research was usually on performance differences between bilinguals and monolinguals on either verbal or nonverbal tasks, and group differences in either kind of task was attributed to bilingualism. The present study is one of the few to investigate the nature and source of bilingual performance differences in both cognitive and linguistic tasks. The pattern of results found here contradicted the hypothesis that both the positive and negative forces affected bilinguals. In judgments of garden-path sentences, there was no group difference between any bilingual and monolingual subgroups, in spite of group differences in English proficiency that were predicted to affect these judgments. One possible explanation is that these groups were based on English lexical knowledge (receptive and expressive English vocabulary) and this grouping was not sensitive to syntactic proficiency level. As shown in the verbal fluency tasks, the categorization was sensitive to lexical retrieval performance and showed the expected pattern. Therefore, levels of lexical knowledge may not represent other aspects of linguistic proficiency, at least not to the syntactic level. It is possible that bilingualism had divergent influences on different levels of linguistic processing. Further research could examine the bilingual influence on lexical and syntactic levels of processing.

Individual studies have shown convincing evidence that these two opposing forces co-exist in bilingual population, but they have rarely been examined together in the same study. These opposing forces, namely the positive force resulting in advantages in nonverbal tasks and negative force resulting in disadvantages in verbal performance, both stem from the same experience, bilingualism. Therefore, there should be a relationship between these two forces in bilinguals, but no such relationship between the forces in monolinguals. The advantage of having the same participants performing the verbal and nonverbal tasks is that the relationship in task performance between these two domains can be examined.

A correlation analysis was conducted to examine the possibility of such a relationship between these forces separately for monolinguals and bilinguals. Raw response times from the flanker and the faces tasks were used to represent cognitive performance (they represent the cognitive variables in the following correlation analysis). Performance in verbal fluency tasks was included to reflect levels of language representation (the language variables). The verbal fluency tasks, letter and category fluency, were chosen because both tasks demand lexical retrieval but letter fluency requires higher levels of cognitive control than category fluency. The relationship between cognitive and language variables were expected to be positive. This expectation was based on the findings reported in chapter 2, that balanced usage and English proficiency were significantly positively correlated. As a consequence of increased use, the language representations in bilinguals would also be stronger. This idea was derived from the weaker links hypothesis (Gollan, et al., 2008) that suggests higher frequency of usage would lead to stronger language representation. Therefore, the general predictions for the correlation analysis were: (1) the cognitive variables (RT from flanker and faces tasks) would correlate with the language variables (number of words produced in letter and category fluency) only in the bilinguals; (2) because cognitive variables were measured by reaction times and the smaller RTs indicated more efficient control, the relationship between the cognitive and language variables would be negative, indicating performance in cognitive variables and language variables vary in the same direction; (3) the correlations between cognitive variables and letter fluency would be stronger than those with category fluency because both cognitive variables and letter fluency required cognitive control.

In chapter 4, it was found that bilinguals with high and low English proficiency differed in their performance in Cattell Culture Fair Test. To ensure that the correlations between the language and cognitive variables were not mediated by the difference in nonverbal reasoning, first-order correlations that partialled out performance on the Cattell

Culture Fair Test were conducted. After controlling for nonverbal reasoning, correlations between the language variables and the cognitive variables derived from the Flanker task did not significantly differ from zero but correlations between the language variables and RTs from the Faces task remained significant. These first-order correlations are presented in Table 22. They confirm that correlations between the cognitive and language variables were only apparent in the bilinguals and not in the monolinguals. Moreover, the correlation coefficients were higher between the cognitive variables and letter fluency than category fluency. Finally, the negative correlations between the cognitive and language variables suggest that bilingual individuals who were efficient in responding to the experimental trials in the nonverbal executive functioning tasks also produced more words in verbal fluency tasks, especially in letter fluency performance. These findings are not surprising because letter fluency, faces and flanker tasks demanded cognitive control and should show a stronger relationship. Category fluency primarily requires language proficiency with minimal level of cognitive control and was not expected to correlate highly with the nonverbal executive functioning tasks.

The correlations between the cognitive and language variables in bilinguals are the first evidence showing the direct relationship between the opposing forces in bilingualism. More importantly, no such correlations were observed in the monolinguals. This suggests that bilingual experience brings together the opposing forces and creates a link between language experience and cognition. When bilinguals retrieve words from either language, the process is effortful and requires cognitive control. The negative

Table 22. First-order correlations between raw response times for faces experimental trials and verbal fluency tasks for monolinguals and bilinguals.

	Straight trials		Gaze trials			
	Green	Red	Green Towards	Green Away	Red Towards	Red Away
			Monolinguals (n = 39)			
Letter	-.00	-.02	-.04	.02	.04	.00
Category	.05	-.00	-.04	.08	.04	.07
			Bilinguals (n = 105)			
Letter	-.30**	-.31**	-.32**	-.36**	-.28**	-.28**
Category	-.14	-.14	-.14	-.17	-.16	-.16

* $p < .05$ ** $p < .01$

correlations presented in Table 22 suggest that bilinguals resolved the nonverbal executive functions task and the lexical retrieval task using similar mechanisms. These mechanisms were related to bilingual experiences that were found to be positively correlated. In the analyses reported in chapters 3 and 4, percentage costs in response time relative to control trials served as dependent variables to assess group differences in nonverbal executive functions. In this correlation analysis, the percentage costs were not used in spite of their cleaner implication because these costs had restricted ranges after being transformed to percentages. As a result, their distributions were not as suitable for linear correlational analyses. The issue of restricted ranges was also confirmed in the correlations. Of the two nonverbal executive functioning tasks, flanker task performance had a smaller variance in ranges than the faces task. This difference contributes to the generally higher correlations in the faces task than those in the flanker tasks.

Other than the issue of restricted ranges, another possible explanation for the low correlation is the lack of comparable scales in cognitive and language variables. Lexical retrieval tasks did not have control conditions like those in nonverbal executive functioning tasks, and it would be difficult to assess costs in the verbal tasks comparable to those in nonverbal executive functions tasks. The closest measure to cost was the primary contrast (standardized difference between letter and category task performance). Considering the costs in nonverbal tasks and contrast in the verbal fluency task, there was only one marginally significant correlation between costs in verbal and nonverbal tasks. No other significant correlation was found in costs and contrast. Therefore, the one marginally significant correlation was deemed unreliable. Future studies could adopt standardized performance scores in nonverbal executive functions, such as other nonverbal subtests in the Delis-Kaplan Executive Functions System, to correlate with the language variables and further examine the relationship between the opposing forces.

Implications of the correlations between the cognitive and language variables indicated bilingual consequences extended to both cognitive and linguistic outcomes. Understanding the consequences of bilingualism is at the core of the intersecting paths of language and cognition. Although the bilingual consequences assessed here point to opposing directions, they stem from the same bilingual experience. When examining the influence of bilingualism, it would be beneficial to understand that this experience affects both language and cognition and it is essential to acknowledge the opposing consequences.

In a recent study (Bialystok, Craik and Luk, in press), young (20 years old) and older (68 years old) bilinguals and monolinguals were included to examine the interaction between bilingualism, cognition and aging. As in this dissertation, both language and cognitive tasks were included. The language tasks were PPVT-III, Boston Naming Task and Verbal fluency tasks while the cognitive tasks were the Simon arrow task, the stroop colour-naming task and the sustained attention to response task. Bialystok et al. (in press) found no correlation between any of the language and cognitive variables in either the monolingual or bilingual groups of young and older adults. Unlike the present dissertation, the bilinguals were fairly homogeneous in levels of balanced usage and English proficiency. In fact, they resembled the BH bilingual profile reported in chapter 2. The lack of correlation between the language and cognitive variables in Bialystok et al. (in press) could be a consequence of the homogeneity of their bilingual sample. With the limited variation in performance and the small sample size (n = 24 in young bilinguals), correlations between language and cognitive variables did not reach statistical significance. In the present dissertation, if only BH bilinguals are considered, all the correlations between language and cognitive variables fall to non-significant levels as well.

The bilingual consequences

In the present dissertation, it was shown that bilingualism is composed of two inter-related dimensions representing different aspects of the bilingual experience, each of which imposes different influences on language and cognition. The third significant contribution of this dissertation is evidence showing the relation between levels of bilingualism along each dimension and their combined effects on verbal and nonverbal tasks.

Nonverbal executive function tasks. The general pattern observed in the majority of the analyses of relative costs in response time (chapter 4) suggested that balanced bilinguals with a high level of English proficiency (BH bilinguals) always had the smallest costs (except for the flanker effect) compared to other bilingual subgroups and monolinguals. The other bilingual subgroups (BL, UH and UL) mainly suffered larger costs than the BH bilinguals (again except for the flanker effect), but did not show a systematic pattern in relation to the monolinguals. The BH bilinguals and monolinguals had the most contrasting language experience in that the BH bilinguals were experienced in managing two languages because of their balanced usage of languages but the monolinguals only used English in both their home and work environments. Other bilingual subgroups often lay in between the BH bilinguals and monolinguals in relative costs analyses. In the analysis of mixing costs for the flanker task, the monolinguals actually suffered smaller costs than the unbalanced bilinguals (UH and UL) in two types of trials.

The pattern of results found for the nonverbal tasks was interesting because bilinguals with a relatively low level of one of the two experiences (the BL and UH bilinguals) did not receive the full benefit of the positive force in nonverbal tasks. In contrast, balanced usage of languages and high English proficiency together often led to the best performance in these tasks. This could be evidence that the positive force requires both high levels of balanced usage of languages and high levels of English proficiency, and the negative force is primarily a reflection of low English proficiency, unrelated to levels of balanced usage.

In addition to reporting balanced daily usage of two language systems, BH bilinguals achieved a high level of proficiency in English even though the majority of them (78%) reported English as their second language. Following them, the balanced bilinguals with low English proficiency (BL bilinguals) and unbalanced bilinguals with high English proficiency (UH bilinguals) had each achieved a high level in one dimension but remained low in the other. Their performance was often between the BH bilinguals and monolinguals, but the UH bilinguals suffered more than monolinguals in the mixing costs analyses. The last bilingual subgroup, unbalanced bilinguals with low English proficiency (UL bilinguals) often performed the worst among the bilinguals, sometimes even worse than the monolinguals. One possible explanation was that UL bilinguals were relatively low in general reasoning skills. This was partially supported by their lower performance on the Cattell Culture Fair Test, although it was still within the normal range (see Chapter 4). With other aspects being similar to other subgroups, e.g., performance on spatial span subtests of the WMS-III, age and years of education, it is unclear why UL bilinguals performed poorly on both verbal and nonverbal tasks. The UH bilinguals were most similar to monolinguals in terms of language usage and proficiency of English. However, their performance was still almost always better than the UL bilinguals.

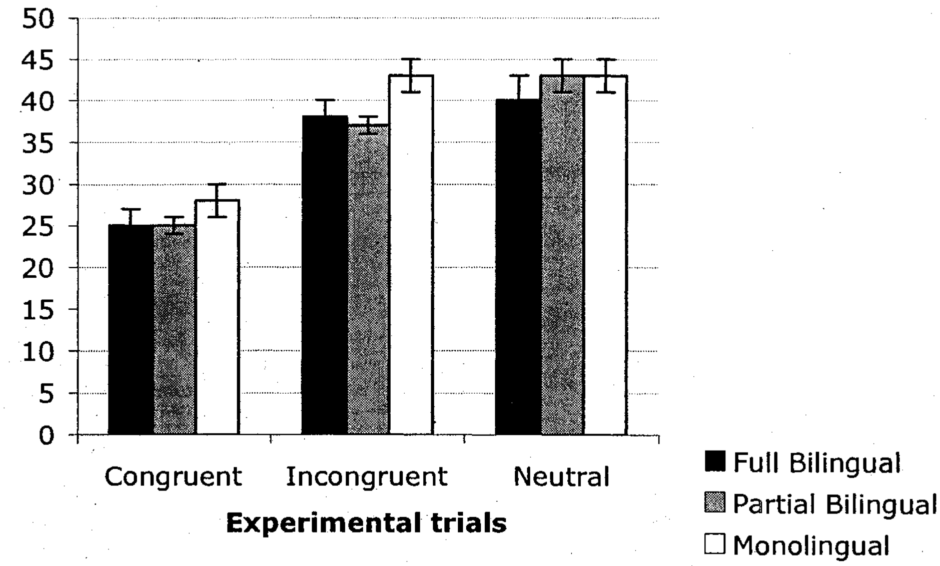
With the five-group analysis reported in chapter 4, it is difficult to identify a systematic pattern in the results. An additional simplified analysis of group differences was therefore conducted for nonverbal executive functions tasks. In this analysis, the BH bilinguals and monolinguals were retained. UL bilinguals were excluded because of their lower performance in the Cattell Culture Fair Test. BL and UH bilinguals were combined to create a group called "partial bilinguals". The term "partial" here refers to being low either on balanced usage or on English proficiency. The BH bilinguals were considered as "full bilinguals" because they attained high levels in both balanced usage and English proficiency. Given the very different sample sizes (22 full bilinguals, 67 partial bilinguals, 39 monolinguals), statistical tests are likely to be unreliable so only patterns are of interest.

Figure 17 presents the percentage change in RT relative to control trials for all the experimental trials in the nonverbal executive function tasks (flanker and faces tasks). In these figures, partial bilinguals sometimes show the same level as the full bilinguals and sometimes align with the monolinguals. This pattern suggests that high levels of at least one dimension of bilingual experience partially enhanced nonverbal executive functions but not as much as high levels in both dimensions.

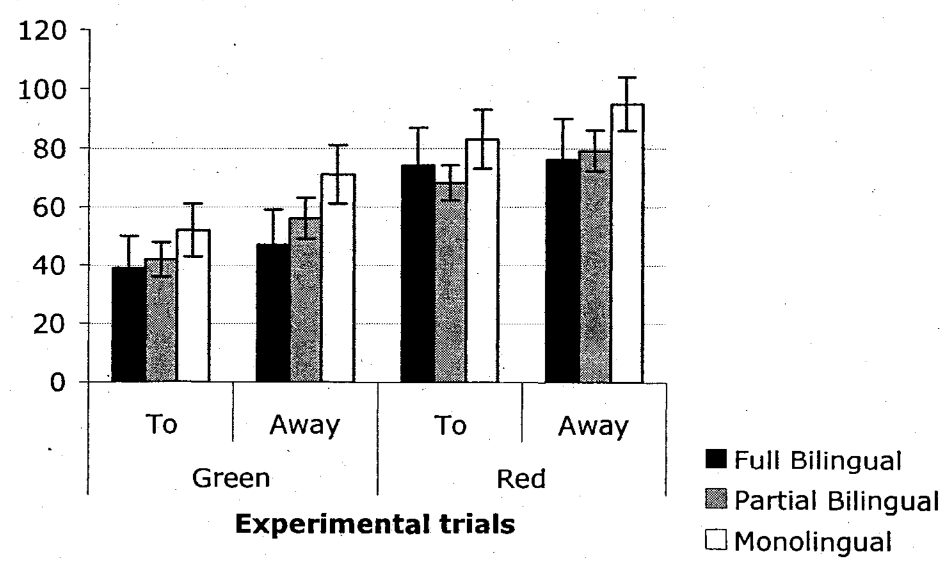
In nonverbal tasks that required executive functions such as control of attention (relative costs for incongruent trials), BH bilinguals experienced smaller costs than monolinguals and the gap between these two groups was filled with other bilingual subgroups. The important implication is that high levels of one dimension of bilingual experience, regardless of which, typically results in small advantages in nonverbal

Figure 17. Percentage change in RT relative to control trials for full bilinguals, partial bilinguals and monolinguals for (a) Chevron Flanker task; and (b) Faces task.

(a) Chevron Flanker task



(b) Faces task



executive functions. In other words, the two bilingual dimensions contribute in concert, giving different degrees of advantages. Future research aiming to further investigate bilinguals' positive consequence in nonverbal executive functions should recruit bilingual participants who have characteristics similar to those described for the BH bilinguals in the present dissertation. Any difference found in task performance would be attributed to bilingual experience, not difference in proficiency of the language of task administration, because these bilinguals should have matching language proficiency compared to monolinguals.

Verbal Tasks. A different pattern of results was obtained for the verbal tasks. The general consensus in bilingual research is that bilinguals have weaker language representation and lower language proficiency in each of their languages. The main hypothesis in the present study was that language proficiency contributes to the level of performance in verbal tasks, with balanced usage providing the extra enhancement in conditions that required executive functions. Therefore, in verbal task conditions that further require cognitive control, bilinguals with a high level of language proficiency should outperform monolinguals. This hypothesis was investigated at two linguistic levels: lexical and sentence-processing.

At the lexical level as measured by the verbal fluency task, bilinguals with high English proficiency (the BH and UH bilinguals), regardless of levels of balanced usage, produced the same number of words in a fixed amount of time as monolinguals in category fluency, a task that does not require cognitive control. In contrast, in letter fluency, a task which requires high level of cognitive control, bilinguals with high

English proficiency, regardless of levels of balanced usage, produced more words than monolinguals and their bilingual peers with low English proficiency. The latter finding has never been reported in previous research because none of the previous studies controlled for participants' language proficiency. The lack of control over language proficiency in previous studies meant that the source of difference in performance (or lack thereof) could be due to either bilinguals' weaker language proficiency (the negative force) or their stronger cognitive control (the positive force), or both. In the present study, it was confirmed that when confounding factors were properly controlled, bilinguals indeed had higher performance in a verbal task that required executive control. Moreover, both the BH and UH bilinguals outperformed the monolinguals in this condition but these two bilingual groups did not differ in performance, indicating language proficiency dominates the contribution to performance, regardless of the level of usage. In other words, verbal performance in bilinguals is only predicted by language proficiency, with no additional benefit from balanced usage of languages.

This pattern of result was very different from those reported for nonverbal executive functions tasks. In nonverbal tasks, no clear pattern was reflected by either bilingual dimension. The only consistent pattern was that the BH bilinguals who were high on balanced usage and English proficiency attained the most efficient performance. Other bilinguals who were high on only one bilingual dimension showed no systematic pattern across the cost variables of different types of experimental trials. Again, this line of evidence suggests that the two bilingual dimensions have differential influence on verbal and nonverbal task performance. In nonverbal tasks, both bilingual dimensions are required to attain the most efficient performance. However, in verbal tasks, language proficiency is the only influential factor.

In another verbal task, namely the sentence grammaticality judgment task, there was no group difference in judging the grammaticality of the garden-path sentences. The garden-path sentences are grammatical in structure but are embedded in an ambiguous syntactic structure. To judge the garden-path sentences as grammatical, participants need to isolate the grammaticality of the sentence from its ambiguous syntax. Despite the language proficiency difference and apparent difference in judgments for control sentences, the bilingual subgroups and monolinguals were equivalent in their judgments of these sentences, although bilinguals with lower English proficiency made more incorrect judgments in ungrammatical and nonsense sentences. This finding was surprising because the bilinguals with low levels of English proficiency were not at a disadvantage in performance. It is possible that grammaticality judgment at the sentence level is not influenced by lexical knowledge (or executive control), which is the dimension that was used to divide high and low level of proficiency in the present dissertation. Another possibility is that the bilinguals' low proficiency level was compensated by their bilingual experience. There is very limited research examining the effects of bilingualism on sentence processing. Moreover, the psycholinguistic models of bilingualism focus more on lexical processing rather than sentence level processing. Therefore, further research should be conducted in this field to explore whether bilingualism affects language processing beyond processing at the word level.

Overall, the bilinguals were found to perform differently from monolinguals in verbal and nonverbal tasks. These differences were related to the degree of experience a bilingual accumulated in each of the two bilingual dimensions. The bilingual advantage in nonverbal executive functions required both balanced usage of the languages and a high level of language proficiency. The bilingual disadvantage in verbal tasks reflected weaker language representations and could be overcome by a high level of language proficiency. With adequate language proficiency, bilinguals even outperformed monolinguals in verbal conditions that required executive control. However, this advantage did not extend to sentence level processing. Future research could extend the present findings and conduct regression type analyses to predict the bilingual advantages in executive functions from levels of bilingualism. In addition, verbal fluency is commonly used as a neuropsychological assessment of cognitive performance, but the influence of bilingualism on performing this task has been understudied, in spite of a growing bilingual population. Examining the task demands involved in verbal fluency and how these demands interact with bilingualism and aging could reform the clinical assessment that includes verbal fluency.

Conclusion

Understanding how everyday experience affects cognition opens a window to investigating the plasticity of the human mind. Through bilingualism, it is possible to examine the consequences of this language experience on cognition. This type of research calls for collaboration of multiple disciplines within cognitive science, such as linguistics, neuroscience, and psychology. Although bilingualism is a language experience, its consequences go beyond the linguistic domain. Compared to monolinguals, the unique experience of being a bilingual is expected in the linguistic domain. However, this experience also shows its influence in cognition. Through the present dissertation, the cognitive and linguistic influences of bilingualism were explored. In addition to the significant findings reported in the dissertation, the results also lead to further questions that could expand the current understanding of bilingualism. On the empirical side, it is important to acknowledge that bilingualism is a multi-dimensional construct. Given this acknowledgement and the understanding of the opposing forces, future research programs that integrate both linguistic and cognitive consequences of bilingualism are in need to increase the understanding of its influence. Empirical evidence could then be integrated to build a comprehensive theoretical model of bilingualism that incorporates multiple bilingual experiences and their influence on both language and cognition.

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Appendix A. Language and Social Background Questionnaire (LSBQ)

Language and Social Background Questionnaire (LSBQ)

Sex: M F Hand: L R Today's date:______________________
Subject ID: ____________________ Date of birth:______________________

How many years have you been registered at the university? ______________________

Have you earned any other degree or diploma prior to the current degree? Yes No

If yes, what is the degree/diploma and how long did it take to complete it? _____
On average, how many hours do you spend on working on a computer every day? ______

Do you play video games? Yes No
If yes, how many hours do you play in a week? ________

Do you speak any languages in addition to English? If yes, please specify the language(s)
____

Do you need to speak/read/write in the non-English language everyday? Yes No

Have you ever lived in a place where the non-English language is the dominant communicating language?
Yes No

If yes, where and for how long? ____

Were you born in Canada? Yes No (If yes, skip the next two lines)

If No, where were you born? ____

when did you first move to Canada? _________________________________

What is your first language? ____

What is your second language? ____

Do you speak any other language(s)? Yes No
If yes, what are the language(s)?___________________________________

In each of the scales below, indicate the proportion of use for English and your other language in **daily life**. These scales are set up for different activities at home or at school/work. On one end of the scale, you have 100 which indicates that the particular activity in that environment is carried out in ALL ENGLISH. On the other end, you have 0 which indicates that you do not use English at all to carry out the activity.

At Home

Speaking — 0 No English ———— 100 All English

Listening — 0 No English ———— 100 All English

Reading — 0 No English ———— 100 All English

Writing — 0 No English ———— 100 All English

Watching TV — 0 No English ———— 100 All English

N/A

Listening to radio — 0 No English ———— 100 All English

N/A

At Work/School

	0		100
Speaking	No English	●——|——|——|——●	All English
Listening	No English	●——|——|——|——●	All English
Reading	No English	●——|——|——|——●	All English
Writing	No English	●——|——|——|——●	All English

Relative to a native speaker's performance, rate your proficiency level in a scale of 0 – 100 for the following activities conducted in your first and second language.

Language # 1: ____________________ (please indicate)

Speaking — Non-native- like (0) ——|——|——|—— (100) Native-like

Understanding (Comprehension) — Non-native-like (0) ——|——|——|—— (100) Native-like

Reading — Non-native- like (0) ——|——|——|—— (100) Native-like

Writing — Non-native- like (0) ——|——|——|—— (100) Native-like

Language # 2: ____________________ (please indicate)

Speaking — Non-native- like (0) ——|——|——|—— (100) Native-like

Understanding (Comprehension) — Non-native-like (0) ——|——|——|—— (100) Native-like

Reading — Non-native- like (0) ——|——|——|—— (100) Native-like

Writing — Non-native- like (0) ——|——|——|—— (100) Native-like

Additional questions about your second language (same as what's indicated as L2 on p. 1):

Where did you learn your second language? Home School Community Work

At what age did you first start **learning** your second language **informally at home**?

____

At what age did you first start **learning** your second language **formally at school**?

____

At what age did you first start **using** your second language actively?__________________________

Did you attend a school that primarily used your second language as medium of instruction?

Yes No

Appendix B. Informed consent form

INFORMED CONSENT
Language Experience and Executive Functions

Sponsor: York University

About the Study
The purpose of the study is to better understand the effect of language experience on various cognitive processes, primarily that of attentional control. We will study young adults who are between the age of 18 and 30 with various kinds of language experience. They will be categorized into five groups based on different levels of language functional use and proficiency. Then performance will be compared across these groups. The procedure in this study has been reviewed and approved for compliance to research ethics protocols by Human Participants Review Subcommittee (HPRC) of York University.

What You are Being Asked to Do
You will be asked to do the following things during the study:

- Answer some questions about your experience learning and speaking English and a second language (not applicable to English monolinguals)
- To watch a computer screen and make decisions about some presented cues.
- To pick out a picture from a series to fit into a puzzle.
- To repeat some tapping sequences on some blocks.
- To listen to a word and select the correct picture from 4 simple pictures and to provide a synonym for a given word.
- To judge whether some sentences are grammatically correct.
- To say as many words as possible that start with a given letter in 60 seconds.

We will provide you with clear instructions and examples at the beginning of each task so that you will know what to do. When using the computer, you will give your answers by clicking a mouse. If you do not know how to use a mouse, we will show you how to use one. We will provide you with breaks throughout the testing time if you wish to take them, and we will answer any questions that you may have. The study will take about 1 hour and 30 minutes to complete. You will be reimbursed $15 or given course credits for the time you spend with the researcher.

Voluntary Participation
Participation in this study is completely voluntary. The decision to participate is entirely up to you.

Risks and Discomforts
We do not expect the study to cause any risks or discomforts for you. However, if you feel uncomfortable or become tired, you can take a break whenever you want. You also have the right not to answer any question if you do not feel comfortable about the questions.

Withdrawal from Study: You can stop participating in the study any time you want, for any reason you want. If you decide to withdraw, you do not need to give a reason, and it will not prejudice your future relations with me, with this university, or any part of this university. Moreover, data collected up until the point you decided to withdraw from the study will be discarded.

Participant's Initial's: ___

Appendix C. Stimuli for the sentence grammaticality judgment task. . The twelve sets of sentences are presented in the following order: (1) Grammatical garden-path sentence; (2) Grammatical non-garden-path sentence; (3) Agrammatical non-garden-path sentence; (4) Agrammatical nonsense sentence.

The mother saw the child would sleep.
The mother who kissed the child would sleep.
The mother see a children sleep.
The mother would sleep the children saw.

The detective charged the criminal was lying.
The detective thought the criminal was lying.
The detective seen the criminals lies.
The detective was lie criminal the charged.

The psychiatrist interviewed the patient was sane.
The psychiatrist determined the patient was sane.
The psychiatrist has seeing the patient was sanity.
The psychiatrist sane was the patient interviewed.

The boy saw the dog was hungry.
The boy who kicked the dog was hungry.
The boy kicking a dogs is hungry.
The boy the hungry saw dog was.

The woman forgot the key was lost.
The woman realized that the key was lost.
The woman lose the keys was forgot.
The woman was the lost key forgot.

The banker understood the market would collapse.
The banker predicted the market would collapse.
The banker was understood the market collapsing.
The banker collapse would market the understood.

The workers saw the policy had changed.
The workers insisted the policy had been changed.
The workers sees the policy to change.
The workers changed saw had the policy.

The police charged the thief would return.
The police who arrested the thief would return.
The police arresting the thief had returns.
The police return thief the charged would.

The officer saw the driver was drunk.
The officer accused the driver was drunk.
The officer see the driver is drinks.
The officer drunk the saw driver was.

The lawyer charged the senator was stealing.
The lawyer who defended the senator was stealing.
The lawyer charging the senator steal.
The lawyer stealing the senator charged was.

The operator understood the caller was taking her time.
The operator who spoke to the caller took her time.
The operator understand the callers taken her time.
The operator taking caller time the caller understood.

The reporter saw the story was big.
The reporter who wrote the story was big.
The reporter writing the story are big.
The reporter big story was the saw.

Note: The longest sentence has nine words. According to Osterhout, Holcomb & Swinney (1994), the average presentation time is calculated by (number of words x 300 ms/word) + (number of breaks between words x 350 ms/break). Based on this calculation, the longest sentence requires 5500 ms presentation time. In order to choose an optimal presentation time for participants with all levels of proficiency, another 1000 ms is added to 5500 ms to ensure sufficient presentation time. Therefore, all 48 sentences will be presented at a fixed duration of 6500 ms.