COGNITIVE CONTROL AND BILINGUAL LANGUAGE DEVELOPMENT: ATTENTION AND EXECUTIVE FUNCTIONS

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Declaration

I, Roberto Filippi, declare that the work presented in this thesis is my own work.

Signed on the 5th of April 2011

Abstract

This research project explores how the development of a second language affects cognitive control in early bilingual children and late bilingual adults. (1) How do bilinguals manage to control their two languages? (2) Does the bilingual experience enhance children's and adults' cognitive functioning? (3) Will brain structures change as a function of increased ability to control both languages? These questions were addressed using behavioural and brain imaging techniques.

Study 1 examined executive function and linguistic skills in early multi-cultural bilingual children, whose performance was compared with age-matched monolingual peers. Study 2 examined probabilistic learning within the same sample of children. Study 3 examined selective attention in late Italian/English bilingual adults, comparing their performance in a within-language and between-language diotic listening task with two monolingual groups, one English and one Italian. Study 4 examined inhibition and cognitive flexibility, comparing bilinguals to monolinguals in a switching diotic listening paradigm. Study 5 shifted the focus on language production, using a word-naming paradigm in which late Italian/English bilingual adults switched between the two spoken languages. Finally, Study 6 examined localised grey matter density variation using structural magnetic resonance imaging (MRI) in the same adult bilingual population.

The results demonstrated: (1) in contrast to some recent research (e.g., Bialystok et al., 2005; Kovács & Mehler, 2009) early bilingual children did not differ from monolingual peers in executive function and probabilistic learning; (2) late bilingual adults did however exhibit an executive control advantage over monolinguals in language comprehension, especially at inhibiting irrelevant information and shifting their attentional set; (3) both languages are active during

speech planning; (4) increased grey matter density in the right cerebellum is associated with efficiency in controlling native language interference.

It is argued that the bilingual experience enhances executive functioning, but this effect was only notable in late adult bilinguals and correlated with different degrees of proficiency, and was observed only in the domain of language comprehension itself.

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List of abbreviations

ACC	Anterior Cingulate Cortex
AoA	Age of Acquisition
BFLA	Bilingual First Language Acquisition
BIA	Bilingual Interactive Activation
BOLD	Blood-Oxygen-Level Dependent
CAU	Caudate Nuclei
DARTEL	Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra
DTI	Diffusion Tensor Imaging
DV	Dependent Variable
DVs	Dependent Variables
EEG	Electroencephalogram
EF	Executive Function
ERP	Event-Related Potential
FA	Fractional Asinotropy
fMRI	Functional Magnetic Resonance Imaging
FWHM	full-width half-maximum
GM	Grey Matter
ICM	Inhibitory Control Model
IV	Independent Variable
L1	First Language (Mother Tongue)
L2	Second Language
MDEFT	Modified Driven Equilibrium Fourier Transform
MNI	Montreal Neurological Institute
MRI	Magnetic Resonance Imaging
PET	Positron emission tomography
PREFR	Prefrontal cortex
SAS	Supervisory Attentional System
SES	Socio Economic Status
SMG	Supramarginal Gyrus
SPM	Statistical Parametric Mapping
VBM	Voxel-based Morphometry
WM	White Matter

Thesis overview

The main aim of this thesis was to investigate how bilingualism affects cognitive control in early bilingual children and late bilingual adults. The thesis is divided into eleven chapters and the tasks used in each experiment are listed in Table A. Chapter 1 introduces the main aims of this research project and describes what is the nature of bilingualism in the contemporary world, how bilinguals are studied and why bilingual research is important for cognition. Chapter 2 reviews theories and main findings on how bilingual experience may affect cognitive control. Chapter 3 presents a brief overview of the methods used, including the experimental paradigms, and the participants who took part in the experiments. Chapter 4 describes the standardised tests used in this research project. Chapter 5 investigates executive function and language skills in early bilingual children and compares their performance to a group of age-matched English monolingual children. Chapter 6 investigates probabilistic learning with the same sample of bilingual and monolingual children. Chapter 7 uses a diotic listening paradigm and a non-verbal executive function task to explore complex linguistic and non-linguistic attentional processes in one group of Italian/English late adult bilinguals and two groups of monolinguals, one English and one Italian. Chapter 8 explores executive function and inhibitory control in a group of late bilingual adults using a diotic listening paradigm and attentional switching between perceptual properties of the speech input. Chapter 9 explores language control in production using a language-switching task in which late Italian/English adult bilinguals named words in both languages. Chapter 10 uses the magnetic resonance imaging technique to explore if the bilingual ability to control interference is related to long-term plasticity in brain structure. Finally, in Chapter 11 the experimental results are discussed in the light of current theories of bilingual cognitive control. Further suggestions are made for future research.

Table A: A complete list of paradigms used in each study of this project (see chapter 4 for citations of published standardised tests).

Study	Task	Description
1, 3 & 6	Simon Task	Executive function task
1 & 2	Coloured Raven's Matrices	Standardised non-verbal reasoning test
1	British Picture Vocabulary Scale	British English Standardised Receptive Vocabulary Test
2	Probabilistic Learning task	Binary forced choice response and conflicting feedback paradigm
3, 4, 5	Ping	Audio/Motor response time assessment
3	Sentence Interpretation - Condition 1 (Dichotic Listening)	Thematic-role sentence Interpretation Task in presence of Native/Non-Native Language Interference
3	Sentence Interpretation - Condition 2	Thematic-role sentence Interpretation Task without Language Interference (Control Condition of the Dichotic Listening Task)
3 & 5	Lexical Decision Task (1)	Online High-Frequency Words and Non-Words (Bilingual and Monolingual versions)
3 & 5	Lexical Decision Task (2)	Off-line Low-Frequency Words and Non-Words (Bilingual and Monolingual versions)
3 & 5	Bilingual Verbal Ability Tests	Standardised test to assess bilingual verbal ability and a measure of English language proficiency.
4	Auditory attention task	Switching between voice perceptual chararacteristics in the presence of conflicting and non-conflicting interference
5	Switching in Production	Word Naming Switching Task
6	Matrices – Subtest of the British Ability Scale II	Standardised Non-Verbal Reasoning Test
6	MRI (Magnetic Resonance Imaging)	Structural brain Scans - Voxel-Based Morphometry and correlations to individual performance in two of the above measures, Simon Task & Sentence interpretation Condition 1 (Matrices employed as covariate)

Chapter 1

Bilingualism

Laura Cogoni "Bilingualism"

Oil on Canvas (30x50cm) – London, 2009

1.1. Introduction

What is bilingualism? I asked this question to an artist, the one who painted the work represented at the beginning of this chapter. She replied: "*Bilingualism is my fourth dimension. It is the way I see things without boundaries, without communication constraints. Bilingualism is a space in which culture flies freely and the mind expands to new fascinating territories.*"

Perhaps this definition of bilingualism is too romantic. However, I feel that it captures the very nature of being bilingual in modern times. According to Beatens Beardsmore (1982) the term bilingualism has an "open-ended semantics". No definition can really explain the complexity of the cognitive, social, educational and cultural factors that are embedded in those who embarked on a bilingual life. In this first chapter I will attempt to describe what is bilingualism in the contemporary world, how it is studied, and why it is important to understand crucial cognitive mechanisms that support it in the human brain.

1.2 A world of bilinguals

The growing interest in bilingual or multilingual speakers is not surprising if we think that more than half of the world's population (about 3 billion people) regularly speaks more than one language (Grosjean, 1982, 2010). As far as Europe is concerned, the European Commission recently published a report (2006) in which a large sample of European citizens were asked how many languages they spoke other than their mother tongue. Fifty-six percent of the people in 25 countries replied that they could have a conversation in a second language, and 28% replied they spoke a third. Great Britain is one of the most "monolingual" countries in Europe; nonetheless, 38% of those polled replied they could speak a second language.

These figures, though impressive, do not tell us much about a potentially bilingual or multilingual population that appears to be a tremendously heterogeneous group. Were the languages learnt early in childhood or later? Are the additional languages used in everyday life? How competent are these people in their second language? These three basic questions are themselves enough to transmit even to the naïve eye how difficult studying bilinguals could be. As Grosjean (1998) pointed out "*…working with bilinguals is a more challenging enterprise* [than studying monolinguals]. *One outcome of this situation is that research dealing with bilinguals has often produced conflicting results*" (p. 131).

1.3 Who are bilinguals

In this research project I will consider bilinguals *"those who use more than one language or a dialect in their everyday life"* (Grosjean, 2010). The inclusion of dialects is particularly relevant here, as part of the project involved Italian participants. In Italy, different dialects are spoken in different regions. These dialects are not just mild inflections from the mother tongue, but proper languages that may significantly differ in syntactic, semantic and phonological properties. For example, someone from Sicily who speaks Sicilian and Italian should be considered as bilingual as someone from Barcelona who speaks Catalan and Spanish. As in most of the Italian regions a dialect can be spoken for historical and cultural reasons, we may say that a considerable proportion of Italians, especially in older generations, are bilinguals. However, there is one region in Italy where the language in use is closest to "pure" Italian: Tuscany. Thus, since part of this research project was focused on Italian and English language processing, a city in Tuscany, Livorno (or Leghorn in English), was chosen to test a group of "truly" monolingual Italian controls.

Another important factor in the general definition of bilingual speakers is related to the regular use of the two languages in life. For example, it is very rare to find someone who has never been exposed to a second language, which is generally a subject taught at school. However, knowledge of a second language may be qualitatively and functionally limited to basic syntactic rules and a small vocabulary, which will be soon forgotten without regular practice. Thus, people who do not use a second language in their every day lives are not considered bilinguals.

1.4 Time of acquisition

As we saw in the previous paragraph, a second language or a dialect can be acquired since birth because it is spoken within the family, the extended family and the rest of the environment. The same may happen in countries where more than one language is officially considered a 'national language'. Easy examples are Switzerland, where French, Italian and German are the official languages, or Canada with French and English. By contrast, a second language may be acquired later in life due to migration to other countries for professional, political or economical reasons. This movement of people around the world generates mixed-language families in which children are raised while exposed to a second language from birth, but this second language may not be culturally shared with the rest of the society.

Many authors categorise bilinguals according to the time they acquired a second language (e.g., Bialystok & Hakuta, 1999; Birdsong, 1992; Genesee & Nicoladis, 1995; Flege, 1999). People who were exposed to two languages from birth are defined as *simultaneous* bilinguals or BFLA (Bilingual first language acquisition - de Houwer, 2005, 2009). In some developmental papers, infants who are exposed to two languages are also described as '*crib bilinguals*' (e.g., Kovács & Mehler, 2009). Bilinguals falling in this category are also defined as *authentic* bilinguals because they can usually master both languages like a native monolingual speaker of each language. A second classification concerns those individuals who learnt a second language prior to first language acquisition being completed, usually before the age of 12 years. They are classified as *early* bilinguals, and people falling in this category usually reach a native-speaker level of competence in L2. However, when compared to simultaneous bilinguals, they may show subtle differences, for example, they may retain some form of L1 accent in L2 (Flege, 1999).

The third category of bilingualism refers to the individuals who learn a second language after having completed the acquisition of their first native language.

They are defined as *late* bilinguals because L2 acquisition usually occurs during adulthood. The case of late bilingualism is particularly interesting because it challenged the standard nativist view for a *critical period* of language acquisition (Lenneberg, 1967). Although it is generally believed that acquiring a second language early is better than late (e.g., de Houwer, 2005; Fabbro, 2004) it was actually shown that adults can learn a second language more quickly than children (Hudson Kam & Newport, 2005). In fact, the concept of a biological clock expiring at a fixed date does not seem to obviously apply to development and researchers now use the term *sensitive period* rather than a *critical* one (see Thomas & Johnson, 2008, for a review).

1.5 Bilingual proficiency

MacNamara (1967) stressed the need to consider the degree of bilingualism not as a unitary component, rather as a level of competence in writing, reading, speaking and listening. In this view, bilingual competence is seen as a continuum in which individuals may vary in the degree of proficiency for each of the four linguistic skills. Thus, measuring how bilinguals master their languages is a crucial issue in bilingual research. Several descriptors are used to define proficient or less proficient bilinguals. One of the most common describes *balanced bilinguals* as those who have an equal mastering of both languages (Lambert, Havelka & Gardner, 1959). Several authors argue that balanced bilingualism is very rare (e.g., Beatens Beardsmore, 1982; Grosjean, 1997). Thus, bilingual individuals may be more *dominant* in one language (L1) and have their second language (L2) as the *subordinate* language. However, it is important to note that the term dominant may apply to a given context in which the language is used. For example, an Italian-English bilingual who studied psychology in England, may use English as a dominant language when discussing psychology-related issues, but may prefer to use Italian when discussing football. Grosjean (1998, 2010) described this contextual language use in his *complementarity principle*, in which multilingual individuals have a preferential use of each language according to the domain or life situation (e.g., within the family, at school, doing sports, going out with friends). Thus, if a language is spoken in more domains, the level of fluency and proficiency will also increase. In contrast, if a language is spoken in a reduced number of domains it will not develop as proficiently.

1.6 Language switching

Bilinguals usually alternate the use of their two languages. This may occur in various ways, from introducing an L2 word when speaking in L1 or vice versa, to completely shifting from one language to another. It was believed that language (or 'code') switching would occur as a form of laziness (see Grosjean, 2010, for discussion); however, switching is a rather common phenomenon, especially amongst bilingual families where the interchangeability of language in use becomes a dynamic part in their communication interaction. Linguistic research has highlighted that code-switching is not just an accidental, ungrammatical blend of two languages, rather it is a language skill which requires a large degree of competence (Poplack, 1980). According to Grosjean (1998, 2001, 2010), bilinguals' code-switching behaviour depends on the interlocutors. Bilingual speakers can function as monolinguals when they speak with people who know only one language. However, they switch to a bilingual mode when interacting with other bilinguals. The *language mode* view implies that bilinguals use their languages along a continuum in which languages are activated or deactivated according to the circumstances. However, as we will see later on in this chapter, there is growing evidence that both languages are active even when only one is in use. The cognitive consequences of language switching will be further discussed in the next chapter.

1.7 Assessing language competence

Self-reported measures

One relatively easy method to collect information is asking for it directly from the individual under a form of questionnaire in which bilingual participants are asked, for example, when they acquired their second language, if they use both languages regularly, and how they self-rate their level of proficiency in reading, listening, writing and speaking. A bilingual measure can be obtained by assigning a score to the relevant questions. Self-reported measures are certainly a valuable source of biographical information. However, they might not provide an exhaustive measure of language proficiency. Issues may arise from a different importance given to factors affecting language acquisition. For example, can the length of residence in a foreign country be considered an index of proficiency? How can knowledge of a language and its proper use be assessed? Moreover, despite the fact that bilingual research has increased in the last 10-15 years, there is no standard questionnaire available. Some attempts have been made to develop a reliable and valid questionnaire, which could predict the relationships with objective measures (e.g., Marian, Blumenfeld & Kaushanskaya, 2007; Tokowicz, Michael & Kroll, 2004). Li, Sepanski and Zhao (2006) developed a web interface based on 41 published studies using language history questionnaires. Although these questionnaires were all different, they showed a consistent degree of overlapping items as, for example, age of L2 first exposure, years of L2 instruction received, language spoken at home. Li and colleagues (2006) identified these recurring items, which were consolidated in a single source. However, despite the authors' intention to add new functions to the interface (e.g., automatic scoring), they did not develop it further.

In summary, although self-reported questionnaires can undoubtedly provide an important source of biographical information, they may not reliably evaluate the individual's level of proficiency. For these reasons, the use of questionnaires is often combined with more objective measures.

Standardised measures

Standardised tests are often used as a means of objective measure to evaluate language competence in bilinguals. However they also may not be exhaustive and their validity can be questioned when not combined with other measurements. Often researchers measure language competence through assessing oral language or receptive vocabulary. This can be a limitation because, as we saw in Chapter 1, competence in a language is a construct that entails other abilities, such as speaking, listening-comprehension, reading, and writing. One of the most used tests in bilingual research to assess competence in English is the Peabody Vocabulary Test (PPVT, Dunn & Dunn 1981). In this test, which can be administered to children and adults also in atypical language development studies, participants are shown a series of slides containing 4 black-and-white numbered pictures. Their task is to indicate the picture associated with what the experimenter says. For example, if the experimenter says “bounce” and on the slide there are pictures of a ball, a spoon, a bicycle, and a computer, the participants will have to indicate the picture of the ball. The PPVT has been also adapted to British English, in the form of the British Picture Vocabulary scale (BPVS II; Dunn, Whetton, & Burley, 1997), which is used in this research project and a more detailed description is provided in Chapter 4. Similar tests are also available in other languages, e.g., the French Echelle Vocabulaire en Images Peabody (EVIP - Dunn, Theriault-Whalen, & Dunn, 1993). Standardised tests reference bilinguals to a monolingual standardisation sample. Perhaps the first attempt to develop a specific test for bilinguals is that produced by Muñoz-Sandoval, Cummins, Alvarado and Ruef (1998), the Bilingual Verbal Ability Tests (BVAT). Their work stemmed from empirical evidence that the bilingual is more than the sum of two monolinguals in one person (Grosjean, 1982). The BVAT is available in 18 different languages, including most Indo-European and Asian languages. It also contains three tests administered individually: (1) Picture Vocabulary; (2) Oral Vocabulary; and (3) Verbal Analogies. The BVAT was also used in this research project and a more detailed description is provided in Chapter 4.

Overall, the existing standardised tests are useful to assess vocabulary knowledge and to estimate the level of competence in at least one of the two languages, and to provide educators with a good estimate of academic comparison with native monolingual speakers. However, they cannot reveal how bilinguals access and control their two languages.

Behavioural measures

A truly balanced bilingual should exhibit a similar level of competence in both languages. Measuring reaction times and accuracy is therefore a valuable method to investigate qualitative differences in the bilingual linguistic functioning. In this research project I used two lexical decision tasks to assess bilinguals' competence in L1 and L2 (Studies 3, 4, 5, 6). One was offline using low frequency words, intended to assess word knowledge, and one was online using high-medium frequency words in both target languages, intended to assess the dynamics of lexical retrieval. The lexical decision task was introduced by Rubenstein and colleagues (Rubenstein, Garfield, & Millikan, 1970; Rubenstein, Lewis, & Rubenstein, 1971). In a typical online lexical decision task setting, participants are required to discriminate words from combinations of letters that do not form words, by pressing one button on a keyboard if the presented stimulus is a word, and another button if it is not. This is illustrated in Figure 1.1. The speed of the response, and the accuracy of decisions are used to measure the difficulty of lexical processing. A lexical decision task administered in a bilingual context might provide a robust dependent measure to assess bilingual competence in both languages.

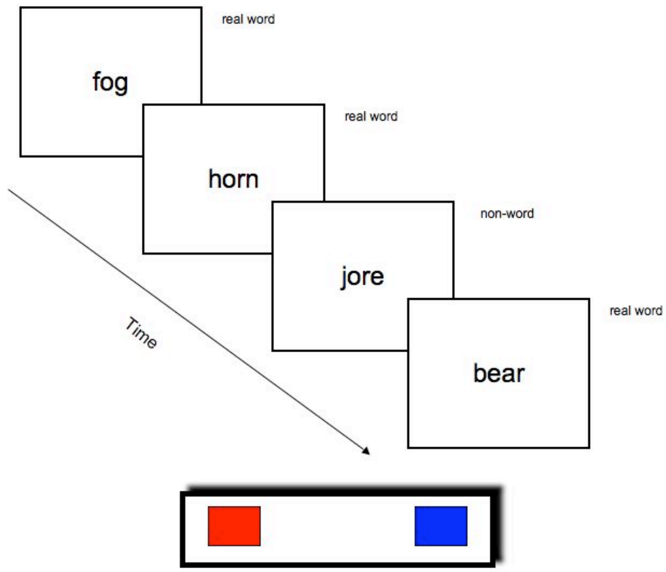


Figure 1.1: A schematic illustration of a computerised version of the lexical decision task. Participants are required to decide if the word presented at the centre of the screen is real or not. Words and non-words are randomised. If the word is real they must press the blue button, if not, the red button. Participants are also asked to make their decisions as fast and accurately as possible.

1.8 Psycholinguistic research: theories, methods and findings

How do bilinguals manage the presence of two languages in a single mind? How do they select and produce speech with one language over the other? How is the bilingual brain organised? How does bilingualism affect cognitive development? These are some of the most important questions that contemporary research on bilingualism is trying to address (Kroll & de Groot, 2005). On the cognitive side, answering these questions would help understand crucial mechanisms that support the use of language. Additionally, the study of the bilingual population has educational, social and medical implications. A large variety of experimental methods have been devised or borrowed from other bodies of research, such as the lexical decision task, word and picture naming, translation, semantic categorization, words fragment completion, free recall and a bilingual version of the Stroop (1935) task. The recent development of new experimental techniques, such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and event related potentials (ERP) have also proved valuable to understand the underlying processes for language acquisition, comprehension and production in bilinguals. The following sections briefly touch on recent views regarding each of the main questions.

How do bilinguals manage the presence of two languages in a single mind?

Weinreich (1953) hypothesised that two languages acquired in the same context produce "compound bilinguals" having two separate phonological representations of words but a common representation of meanings, whereas two languages acquired in different contexts produce "coordinate bilinguals" having sounds and meanings separate for each language. This terminology changed over time: the "Common or Shared Store" vs. the "Independence" hypotheses (McCormack, 1977), or the "Single Code" vs. "Dual Code" hypotheses (Durgunoglu & Roediger, 1987).

Early studies with Hindi-English and French-English bilinguals (e.g., Kirsner, Brown, Abrol, Chandra & Sharma, 1980; Kirsner, Smith and Lockhart, 1984; Scarborough, Gerard & Cortese, 1984), showed the subjects responded faster when presented a word within the same language twice (repetition priming effect), but this facilitation did not occur in a between-language condition. Based on the assumption that repetition priming results from accessing the same representation twice, the authors concluded that the two languages in a bilingual speaker are represented separately.

Several models attempted to explain the dynamics of the bilingual lexico-semantic system, focusing on the way in which words and concepts are interconnected across the two languages. These models derived from studies considering how single words and sounds are retrieved and spoken in an adult learner of a second language. For example, Ervin and Osgood (1954) proposed that language representations are mediated by the modalities in which L2 is acquired. An individual learning two languages in two culturally separate environments, will develop different lexico-semantic representations, one for each known language. On the other hand, a bilingual learning both languages in the same cultural context will develop two lexicons associated to the same conceptual system. Finally, those who learn a second language later in life, will develop a subordinate system in which L1 mediates the access to concepts: the meanings of words in L2 are accessed only through a translation process. Potter, So, Von Eckardt and Feldman (1984) proposed a *word association* and a *concept mediation* model based on Weinreich's (1953) subordinate and compound systems. The *word association* model reflects the organisation of both languages in a low-proficient bilingual. L2 words do not have direct access to the conceptual level. However, those who have reached a high degree of proficiency in L2 will have lexical items of both languages directly associated to the conceptual system. The two models combined entail a developmental hypothesis of language representation in bilinguals (i.e., from low to high L2 proficiency). Empirical evidence confirmed the role of language competence (Chen & Leung, 1989; Kroll & Curley, 1988). Low and high proficient bilingual participants were asked to name pictures and translate words in both languages, under the assumption that picture naming involves a conceptual mediation strategy, whereas translating words requires a lexical translation strategy. In fact, it was found that low proficient bilinguals were faster when translating words than naming pictures, exhibiting the use of a lexical translation strategy. On the other hand, high proficient bilinguals' performance was comparable across both tasks, suggesting the use of a concept mediation strategy.

This evidence supported the idea of a shift from a *word association* to a *concept association,* which is mediated by the degree of proficiency in L2. However, in a number of empirical observations, it was found that both low and high proficient bilinguals were faster and more accurate in translating from L2 to L1 than from L1 to L2. Kroll and Stewart (1994) explained this asymmetry in terms of the strength of the links between words and concepts in both languages, and merged the two models into a single developmental theory, the Revised Hierarchical Model. We will return to consider this model in greater detail in the chapter devoted to language control and speech production (Chapter 9).

How do bilinguals select their languages?

The psycholinguistic models described above are advantageous in that they can account for changes in a bilingual's proficiency over time, but none of them were able to explain how bilingual speakers select one language over the other.

MacNamara and Kushnir (1971) proposed the *two-switch theory* based on the evidence that bilinguals take longer to name or read mixed-language lists of words. In this theory, it is assumed that bilinguals control their two languages through an automatic input switch for comprehension and a voluntarily controlled output switch for speech production. Studies using a bilingual version of the Stroop (1935) paradigm seemed to confirm the two-switch theory: bilingual subjects asked to name the colour of the words presented in both languages could not prevent themselves from processing semantically a word in the task-irrelevant language (Dyer, 1969; Preston & Lambert, 1969).

Non-selective view for language comprehension

More recent studies tend to reject the two-switch theory in favour of a non-selective process for language comprehension (e.g., Dijkstra, Van Jaarsveld & Brinke, 1998; Van Hell & Dijkstra 2002; Von Studnitz & Green, 2002). These studies predominantly used the lexical decision paradigm with words that shared the same characteristics in both languages such as, for example, the Italian word *dose*, that has the same spelling and meaning in English. A computer-simulated model of lexical access, the Bilingual Interactive Activation (BIA and BIA+) provides support that alternatives in both languages are available and activated in parallel (Dijkstra & Van Heuven, 2002). The specific empirical effects that supported this conclusion are covered in more detail in Chapter 9.

Inhibitory processes for language production

The cognitive mechanism underlying the selection of two competing languages in a single mind is represented in the Inhibitory Control Model (Green, 1986, 1998). The model implies that once a target language is selected, the language that is not going to be used is inhibited. Similarly to the BIA and BIA+, the Inhibitory Control Model also predicts that language activation occurs in a non-selective fashion, that is, both languages are activated in parallel and compete for selection. Experimental evidence in support of this view was provided using task-switching paradigms in which bilingual participants are required to name the presented stimuli (i.e., digits, pictures or words) alternating the target language (e.g., Meuter & Allport, 1999). The debate on inhibitory processes for language selection is still unresolved. Other authors proposed different views explaining experimental evidence in terms of both inhibitory and facilitatory processes (e.g., Costa, Miozzo & Caramazza, 1999; Costa, 2005). The overriding observation is that bilinguals can speak in one language at a time, even when that language is of low proficiency. The mechanisms that permit such control and their real time dynamics, are as yet unclear. The issues related to language selection and switching will be covered in more detail in Chapter 9.

How does bilingualism affect cognitive development?

The question "*is bilingualism bad for cognitive development?*" has been around for a long time. The people who are more concerned with this question are generally the parents and educators of bilingual children (Chin & Wigglesworth, 2007). Early research exclusively highlighted the negative effects of bilingualism. The German philosopher and linguist Wilheim von Humboldt (1836) argued that the essence of each individual's language could be only preserved through pure monolingualism. The first empirical evidence negatively influenced decades of research on the topic. In a series of studies, Saer and colleagues (1922, 1923) found that bilingual children in Wales were significantly inferior to monolinguals in a range of tests, including general intelligence (IQ) tests. Similar results were obtained by Pintner and Keller (1922), who compared English monolinguals and bilingual children of Italian and Spanish immigrants. These studies contained serious methodological flaws in that they did not account for socio-economic status (SES). Bilingual children in both studies were either from working-class or disadvantaged families, whereas the monolingual children were from middle-class families. Other studies confirmed the bilingual inferiority in both verbal and non-verbal tasks (see Darcy, 1953, for a review). English language was the medium used for testing bilinguals, adding an additional confound: being tested in the weaker language was one of the reasons why bilinguals performed poorly compared to English monolingual speakers.

Despite all these issues, the first half of the 20^{th} century was characterised by the general opinion that bilingualism was detrimental to cognitive functioning.

However, some studies reported that when bilingual children had a more regular use of their second language (i.e., speaking English at home), they performed better in the tests (Arthur, 1937; Bere, 1924). Once age and SES were carefully matched between bilingual and monolingual children, no differences were found in measures of intelligence (Arsenian, 1937). Other researchers highlighted the strong correlation between performance and SES rather than language status (McCarthy, 1930; James, 1960). Four decades of findings were questioned until the turning point came in 1962 when Peal and Lambert published a work that reshaped completely the negative view on second language acquisition. The study was conducted in Canada involving 364 French/English bilinguals and English or French monolingual 10-year old children, who were strictly matched by age, SES, language, intelligence and sex. Results revealed that when these variables were properly controlled bilinguals outperformed monolingual peers in a variety of tests measuring intelligence, in particular those involving symbolic manipulation. Peal and Lambert (1962) called this ability *cognitive flexibility* and were the first to propose that the bilinguals' early skill of managing two languages may have enhanced the development of general cognitive aspects. The authors characterised a bilingual child as "*a youngster whose wider experiences in two cultures have given him advantages which a monolingual does not enjoy. Intellectually, his experience with two language systems seems to have left him with a mental flexibility, a superiority in concept formation, a more diversified set of mental abilities.... In contrast, the monolingual appears to have a more unitary structure of intelligence which he must use for all types of intellectual tasks*" (p.20).

The Peal and Lambert (1962) study radically changed previous views and spurred a new generation of researchers to develop new methods to investigate the relationship between bilingualism and cognitive control.

1.9 Conclusions

In this chapter, I discussed the main issues connected with the concept of bilingualism, and outlined the aims and plans of this research project. I described in particular the importance of assessing bilingual competence, and the main theories and findings from behavioural research related to language representation and control. I also introduced the topic of the consequences that second language acquisition may have on cognitive development by providing a historical perspective, which highlighted the negative aspects of bilingualism. In the next chapter I will focus on cognitive control and the empirical evidence suggesting that bilingualism may enhance executive functioning in children and adults. Moreover, I will discuss how modern neuroimaging techniques may help reveal the underlying cognitive architecture of language use.

Chapter 2

Bilingualism and Cognitive Control

2.1 Introduction: What is cognitive control?

In our everyday life we often face novel situations that require different plans of action (or decision making). Such actions must be flexible and adaptive, errors must be corrected, plans might require changes (or switches), others must be put aside (or inhibited). These processes need deliberate or *controlled* attentional resources and must be distinguished from *automatic* processing (Norman & Shallice, 2000), which may not necessarily involve conscious awareness, voluntary control or interference with other actions/tasks. Controlled actions need to be supervised by a mechanism called *cognitive control* (Miller & Cohen, 2001), which is also referred in the literature as to *executive function* or *supervisory attention* (Shallice, 1998). In summary, cognitive control is a theorised system in psychology, which supervises voluntary actions for decision making, cognitive flexibility, selective attention, abstract thinking, switching and inhibition (Posner & Snyder, 1975). Despite cognitive control being at the heart of human cognition, there is still a lack of knowledge about how all these executive functions are coordinated (Monsell, 1996). The most prominent theoretical framework defines cognitive control as a system composed of subprocesses. For example, according to Baddeley (1986, 1992) a central attention system regulates various subprocesses (a view also shared by Norman and Shallice, 1986). However, another theoretical approach postulates that executive functions are dissociable (e.g., Diamond, 2001, 2002). A recent study by Miyake, Friedman, Emerson, Witzki and Howerter (2000) moved on from the debate concerning the unitary and componential theories and attempted to provide empirical evidence for developing a new framework that would explain how cognitive processes are organised. They targeted three components of cognitive control that are frequently postulated in the literature (e.g., Baddeley, 1986; Smith & Jonides, 1999):

(1) mental set shifting; (2) information updating and monitoring, and; (3) inhibition of prepotent responses. The tests used in the study are summarised in Table 2.1. The main aim of Miyake and colleagues (2000) was to statistically extract commonalities and differences within each of the three components of executive function.

Table 2.1: Tasks administered by Miyake et al. (2000). The table has been adapted from Garon, Bryson and Smith (2008).

Cognitive Control Component	Task	Description
Inhibition	Antisaccade	A visual cue is presented to the left or right on a computer screen, followed by a target (e.g., an arrow) on the contralateral side. Participants are asked to inhibit looking at the cue and respond to the target by pressing a button indicating the direction of the target.
Inhibition	Stroop	Participants are asked to verbally name the colour of a stimulus as quickly as possible. Incongruent trials include colour words printed in a different colour (e.g., RED printed in BLUE colour).
Inhibition	Stop Signal	There are two conditions: (1) participants perform a categorisation task; (2) participants are asked to inhibit doing the task when they hear a computer tone.
Shifting	Number Letter	Number-letter pairs are presented in one of 4 quadrants. Participants must indicate whether the numbers are odd or even (upper quadrants) and whether letters are vowels of consonants (lower quadrants).
Shifting	Plus-minus	Participants are required to add 3 to a list of numbers. Then they have to subtract 3 from another list of numbers. Finally they alternate additions and subtractions of 3 on a third list of numbers.
Shifting	Local-global	Participants are shown a global figure made of small local figures. If this is blue, they must say the numbers of lines in the global figures, if it is black they must say the number of lines in the local figure.
Working memory	Letter memory	Letters are presented serially and participants are asked to recall the last four of each list.
Working memory	Keep track	Participants are shown several lists of items and asked to keep track of the last item of each list.
Working memory	Tone monitoring	Participants are presented low, medium and high pitches tones and required to respond to a particular tone after four times this was presented.
Shifting	Wisconsin Card Sort test	Participants are asked to match cards by color, design or quantity.
Inhibition	Tower of Hanoi	Participants are asked to move a pile of disks from position A to B following certain rules
Working Memory	Random number generation	Participants are required to say aloud a number after a computer beep. The number, from 1 to 9, has to be generated as random an order as possible
Working Memory	Operation Span Task	Participants are given equation-word pairs and they are required to verify the equation and read aloud the word.

Factor analysis showed that updating, shifting and inhibiting components are separable, although sharing some underlying commonality. Miyake et al. (2000) proposed a cognitive control model in which both unitary and componential frameworks were confirmed in a single theory. Moreover, the authors found that some tasks were more efficient than others in measuring executive function processes. For example, shifting ability was associated with performance in the Wisconsin card sort task, inhibition ability played an important role in solving the Tower of Hanoi task, and updating ability was best measured with the operation span task, a measure of verbal working memory capacity.

From a developmental perspective, Piaget (1954) argued that the first signs of what we would today call executive function start at about 8-9 months of age. This period belongs to the *sensorimotor stage 4* of his theory of cognitive development. By this age an infant is able to intentionally look for a non-visible object and perform a goal-directed sequence of actions. This ability has been empirically demonstrated in several studies with infants (e.g., Diamond, 1990, 1991). In the A-not-B task, for example, an attractive toy is hidden in box A, within the baby's reach. The trials are then repeated several times (habituation process) until the toy is hidden in box B. Younger babies generally make the perseverance error, that is, they continue to look in box A. By 1-year of age they do not make this error anymore (e.g., Bell & Adams, 1999; Gratch, 1975). Behavioural changes in the first year of life are attributed to maturation of specific brain regions, in particular the prefrontal cortex, or PFC (Diamond & Goldman-Rakic, 1989; Diamond, 1991). As we will see later on in this chapter, the PFC is considered the locus of control for executive function abilities (Abutalebi & Green, 2007). Several studies exploring the development of executive control have shown that adult levels of performance not achieved until adolescence, around the age of 12-year old (Luciana, 2003).

2.2 Bilingual advantages in cognitive functioning

As already discussed in the previous chapter, early studies highlighted the negative effects of bilingualism in cognitive functioning. After Peal and Lambert's (1962) seminal study, research focused on the positive effects of bilingualism in cognitive development. There is growing evidence that the bilingual experience, either starting in infancy or later in adulthood, may provide marked cognitive advantages in a range of linguistic and non-linguistic tasks, especially those requiring ignoring irrelevant information and shifting. As Bialystok put it: "…*bilingualism may have the salutary effect of boosting control processes in non-verbal domains because those same general processes are required to manage two-language systems*" (Bialystok et al., 2005, p.40).

Linguistic advantages: metalinguistic awareness

The term metalinguistic awareness refers to the ability to understand linguistic structure. The first case of a possible bilingual advantage for language analysis was reported by Leopold (1949), who observed his little daughter's precocious skill with rhymes. He argued that her early exposure to two languages made her more sensitive to detaching sounds from meanings and this ability could give a bilingual child a linguistic advantage over monolinguals. Subsequent research on metalinguistic awareness confirmed Leopold's intuition. Bialystok (1986) used a grammatical judgment paradigm with bilingual and monolingual children from 5 to 9-year of age. Children were asked to decide if a presented sentence in English was grammatical or not (e.g., Apples *grows* on trees; Apples *grow* on trees). Additionally, they were required to judge if a sentence could be considered acceptable, that is, grammatically correct but strange in meaning (e.g., Apples grow on *noses*). The results showed that monolingual and bilingual children had comparable performance when judging grammatically correct sentences. However, bilinguals showed an advantage over monolinguals in judging whether sentences with strange meanings were grammatically correct. Further investigations using the symbolic substitution paradigm confirmed a bilingual advantage in the awareness of the arbitrariness of language. In this paradigm, children are shown, for example, a toy *aereoplane* and told that from that moment on the toy is called *turtle*. Following this logic, at the experimenter's question "*can the turtle fly?",* they should reply yes. Bilingual children speaking a variety of languages outperformed monolingual children in these studies (Ben-Zeev, 1977, Cromdal, 1999; Ianco-Worrall, 1972). Bilinguals also showed an advantage in phonological awareness, that is, the ability to recognise that speech is composed of distinct sounds (Davine, Tucker & Lambert, 1971) and in sentence awareness, that is, the ability to recognise utterances which are grammatically correct within the language (Galambos & Goldin-Meadow, 1983). Although some studies failed to replicate previous findings, for example on a bilingual advantage for phonological awareness (Bialystok, 1988), overall research on metalinguistic awareness has shown a bilingual superiority over monolingual speakers. In general, Galambos and Hakuta (1988) found that more proficient bilinguals had better performance than low proficient bilinguals. Cummins (1978) tried to explain inconsistencies in this field with his *Threshold hypothesis*, which postulated that a minimum level of language competence is required to attain cognitive benefits from being bilingual. The problem with the *Threshold* theory is establishing what is the optimal threshold in concrete terms. Nonetheless, some studies (e.g., Galambos & Hakuta, 1988; Ricciardelli, 1992) confirmed that bilingual performance across a range of tasks improved with increased levels of language proficiency. In contrast, Bialystok (1988, 2008) proposed a model where bilinguals, irrespective of their degree of proficiency, may be more advantaged in tasks that require controlled attention and inhibition.

Non-linguistic advantages in bilingual children and adults

As we saw in chapter 1, there is growing evidence showing that both languages are active in parallel in the bilingual mind. Therefore, to hold a meaningful conversation bilinguals are required to select one language and suppress the other. Two important questions are raised in current bilingual research: (1) if language selection involves attention, is this process controlled by the same mechanisms that are used in general cognitive functioning or are they specific to language? (2) If they are general control mechanisms, can their constant use affect bilingual cognitive functioning? Answers to these questions can be addressed by investigating whether bilinguals exhibit a general advantage in mechanisms of attentional control. Thus, if bilinguals use mechanisms of attentional control that are not specific for language, differences between bilinguals and monolinguals should be found in non-verbal tasks requiring control of attention. In addition, as control processes involved in inhibition mature later in children (Diamond, 2002), the extensive cognitive training deriving from the use of two languages may have a positive effect on the bilingual children's cognitive system.

One of the first attempts to answer these questions was investigating the development of attentional processes in different domains, such as the concept of cardinal quantities. Bialystok and Codd (1997) tested monolingual and bilingual children from 4 to 5-year old using the tower task and the sharing problem task.

In the tower task, children were shown pairs of towers made of *Lego* and *Duplo* blocks. All blocks had the same color and structure but a Lego block was half the size of a Duplo block, making the Lego towers half of the size of a Duplo tower.

Children were shown pairs of towers and told that each block represented an apartment of various dimensions in which just one family lived. Children were asked to count the blocks and choose the tower with more families. Pairs were either matched (e.g., towers made of the same type of blocks) or unmatched (e.g., towers made of different blocks). Unmatched pairs contained conflicting information (e.g., the Lego tower was smaller but had more blocks that the Duplo tower). Thus, if children relied on the perceptual cue to answer, they would not give the correct response. In order to resolve this task, they should count the blocks and, at the same time, ignore the distracting information given by the height of unmatched towers.

In the sharing task, children were told to share a quantity of items between two dolls following a one-for-you one-for-you logic. When the items were evenly shared, the children were asked if the two dolls had the same quantity of items. Whereas no difference was found between groups in the sharing task, bilinguals outperformed monolinguals in the task requiring attentional control (the unmatched pairs of the tower task).

Other tasks contain conflicting or misleading information, such as the dimensional change card sort task (DCCS, Zelazo, Fryes & Rapus, 1996), and the Simon task (Lu & Proctor, 1995; Simon & Wolf, 1963) are often used in bilingual studies. In the DCCS task, children are required to sort 12 test cards, e.g., 6 red and 6 blue, following two explicit rules in conflict with one another, e.g., put the red cards in the red box, or put the red cards in the blue box. In the pre-switch trial children are told to follow one rule and in the post-switch trial children are told to ignore the previous rule and follow the other one. In the Simon task, the participants' reaction times and accuracy are measured while they are required to press a left or a right button on the keyboard when a stimulus (e.g., a blue or a red square) appears on the left hand side or the right hand side of a computer screen. The buttons are associated with a colour (e.g., right for blue and left for red) and this association leads to congruent trials (i.e., the stimulus position is compatible with the position of the button) or incongruent trials (i.e., stimulus and button positions are incompatible). As the Simon task was also used in this research project, some further discussion is warranted. In the Simon task, the participants' reaction times and accuracy are measured while they are required to press a left or a right button on the keyboard when a stimulus (e.g., a blue or a red square) appears on the left hand side or the right hand side of a computer screen. The buttons are associated with a colour (e.g., right for blue and left for red) and this association leads to congruent trials (i.e., the stimulus position is compatible with the position of the button) or incongruent trials (i.e., stimulus and button positions are incompatible). The participants' response to congruent trials is faster than to incongruent trials and the responses with incongruent trials, a phenomenon known as the Simon effect (Craft & Simon, 1970; Simon, 1969; Simon & Berbaum, 1990; Simon & Rudell, 1967). Clearly, the non-target (irrelevant) information about the stimulus location cannot be excluded from processing even though the subjects are instructed to do so beforehand. It is generally assumed that the Simon effect is generated by the parallel activation of two routes, the *conditional* and the *unconditional* route, that coordinate perception to action. The appropriate response in the *conditional* route is activated intentionally and relatively slowly. In contrast, in the unconditional route, the participant's response associated to the spatial location of the stimulus is activated more quickly and in an automated fashion (de Jong, Liang, & Lauber, 1994; Eimer, 1995; Kornblum, 1994; Kornblum, Hasbroucq, & Osman, 1990; Ridderinkhof, 2002b; Wiegand & Wascher, 2005). Kornblum (1994) argued that the response set and the irrelevant stimulus shared the same dimension, that is, spatial location. As a result, participants performing the Simon task automatically associate their motor response to the location of the relevant stimuli. In contrast, as the position of the irrelevant stimulus varies causing interference, participants' response slows down due to strategic mechanism (de Jong et al., 1994; Eimer, 1995; Ridderinkhof, 2002b; Wiegand & Wascher, 2005).

The Simon task offers a unique opportunity to test both young children and older adults (it is neither trivially easy for an adult, nor extremely difficult for a child), and the size effects reported in the literature are generally large even with a small number of trials and participants (e.g., Bialystok et al., 2004).

Results from both paradigms revealed a bilingual advantage over monolinguals in shifting between rules (DCCS) and in responding faster to incongruent trials in the Simon task (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008). These studies are described in more detail in chapters 5, 6 and 7. Bialystok and colleagues (2004) proposed that lifelong experience of managing two languages in a single mind might attenuate the decline of cognitive processes as age increases. However, it was also shown that executive control advantages either disappear or are attenuated within the younger population (Bialystok, Martin & Viswanathan, 2005; Bialystok, Craik & Ryan, 2006). Costa, Hernandez and Sebastián-Gallés (2008) used a different paradigm, the Attentional Network Task (ANT - Fan et al., 2002) with young bilingual and monolingual adults (mean age 22-year old). The ANT task is predicted on the assumption that there are three different attentional networks: (1) alerting; (2) orienting, and; (2) executive control (see also Posner & Petersen, 1990). Participants are required to indicate whether an arrow presented at the centre of a computer screen (target stimulus) points either to the right hand side or to the left hand side. The arrow is flanked by other arrows pointing either in the same or in a different direction of the target stimulus. Typically, participants respond faster when the target and the flanker stimuli all point to the same direction (congruent trials) than when they point to the opposite direction (incongruent trials). Thus, in order to successfully perform this task, participants must ignore the conflicting information given by the flankers involving executive function processing. Additionally, a cue is presented before the target stimulus to investigate the alerting network. In this condition, participants exhibit a better performance (i.e., faster reaction times) when a cue precedes the target stimulus. For the orienting network, a cue placed either on the right hand side or the left hand side of the screen, signals the position where the target stimulus would appear. In this condition, the participants' performance is faster when the cue signals the position of the target than when it does not. Costa and colleagues (2008) found that young adult bilinguals were faster than monolinguals in performing the task irrespectively if the trials were congruent or incongruent but they were overall more efficient with incongruent trials. Moreover, they took more advantage of the alerting cue than monolinguals. These results overall confirmed Bialystok's view for a bilingual advantage in cognitive control throughout lifespan (Bialystok et al., 2004, 2005)

2.3 Cognitive control advantages in bilinguals: Why?

One explanation of the bilingual advantage in non-verbal executive function task stems from the assumption that bilinguals continuously need to control their two languages by focusing on the target language and avoiding interference from the unintended one (e.g., Costa, La Heij, & Navarrete, 2006, Finkbeiner, Allmeida, Janssen & Caramazza, 2006; Green, 1998; Meuter & Allport, 1999). This extensive cognitive "overtraining" may in turn produced a benefit in resolving the conflict between competing information beyond the language system. Thus, conflict may be resolved by domain general executive control mechanisms (Abutalebi & Green, 2007; Bialystok, 2001).

However, this interpretation faces at least two problems: (1) differences between bilinguals and monolinguals are not always found (Colzato et al., 2008; Morton & Harper, 2007); (2) if these differences are real, there is no sufficient evidence that they can be attributable only to inhibitory processes (Bialystok, 2010).

For point one, for example, Morton and Harper (2007) failed to replicate Bialystok and colleagues (2004) findings using the Simon Task. They compared the performance of bilingual and monolingual children aged 6 to 7 years and found no differences between the two groups in executive functions. However, a closer analysis of the data revealed that best performance in the Simon Task was correlated with socio-econonomic status rather than linguistic status. We will return to this issue later on in this research project (Chapters 5, 6 and 7). For point two, bilinguals have shown attentional advantages over monolinguals even when the task did not imply any obvious cognitive difficulty, that is, responding to a congruent trial (e.g., Bialystok et al., 2006; Costa et al., 2008; Martin-Rhee & Bialystok, 2008). This phenomenon could be explained in terms of language monitoring, rather than inhibitory processes. As we saw in Chapter 1, bilinguals often switch between languages in normal conversations (Grosjean, 1992), an ability that in turn might enhance general monitoring processes (Costa, Hernandez, Costa-Faidella & Sebastián-Gallés, 2009).

In summary, no single study can explain where the bilingual advantage in cognitive control stems from. However, new research (e.g., Bialystok, 2010) suggests that the explanation might not be solely confined to an inhibition mechanism, but expanded further to attentional processes such as monitoring and shifting.

2.4 Negative effects of bilingualism

As we have seen so far, current bilingual research has dissipated previous beliefs that second language acquisition may have a detrimental effect on cognitive development. However, whilst bilingualism seems not to have any particular effect in some areas, for example, bilinguals and monolinguals have comparable performance with tasks measuring working memory abilities (Bialystok, 2008), some negative aspects are still reported in the current literature. It is obvious that those who possess more than one linguistic representation face a greater degree of complexity than those who speak only one language. The complexity of bilingual lexical access lead several authors to anticipate a bilingual disadvantage in tasks requiring speech production (Ivanova, Costa, 2008; Gollan, Silverberg, 2001; Gollan, Montoya & Werner, 2002). For example, Kohnert, Hernandez and Bates (1998) found that bilinguals scored below the norms on a standardised measure of object naming, the Boston Naming test. Portocarrero, Burright and Donovick (2007) compared the performance of early bilingual and monolingual college students with measures of English vocabulary and verbal fluency. The results showed that bilinguals had lower receptive and expressive vocabularies and semantic fluency scores than their monolingual peers. Bilingual children are generally reported to develop vocabulary more slowly in each language than monolingual speakers within each language (e.g., Bialystok & Feng, in press; Oller & Eilers, 2002).

In addition to vocabulary size, disadvantages are also found in accessing lexical representations, or lexical retrieval. For example, in verbal fluency tasks, participants are asked to produce as many words as possible within a time frame of 60 seconds. The words must belong to the same semantic category (e.g., animals, fruits, vegetables) or phonemic category (e.g., words beginning with A, C, G). Studies comparing the performance of linguistic groups, demonstrated that bilinguals produced fewer words than monolingual peers (e.g., Gollan et al., 2002; Rosselli, Ardila, Araujo, et al., 2000). Bilingual disadvantages in lexical access are also evident with reaction times measures in picture naming tasks. Gollan, Montoya, Fennema-Notestine, and Morris (2005) asked English monolinguals and early English-Spanish bilinguals to classify and name pictures. Bilinguals were slower and less accurate than monolinguals in naming pictures, showing the same disadvantage even when the task was repeated for three times. However, bilinguals' and monolinguals' performance was comparable in the picture classification task. The results combined, clearly showed that bilinguals were disadvantaged in lexical access. Ivanova and Costa (2008) found that Spanish-Catalan bilinguals were slower than Spanish monolinguals both when they were assessed in their first and their second language and there is evidence that the bilingual disadvantage in lexical access is constant with age (Gollan et al., 2007). Finally, bilinguals speaking a variety of languages are reported to experience more tip-of-the-tongue errors (TOTs), that is, failure to retrieve well-known words (e.g., Gollan & Silverberg, 2001; Gollan & Acenas, 2004).

Michael and Gollan (2005) explained the bilingual lexical access deficit in terms of "weaker links", or weaker connections required for rapid and fluent speech production. The weaker links model predicts that bilinguals have weaker lexical connections because they use each language half of the time compared to a monolingual who speaks only one language 100% of the time.

Another possible explanation is that lexical access deficit is caused by cross-language competition of related items (Green, 1998). As we saw above, competition for selection requires a mechanism that may inhibit the non-target language in favour of the target one. This mechanism may in turn enhance cognitive control. Thus, negative side and positive side of bilingualism might be two faces of the same coin (Bialystok, 2008).

2.5 The bilingual brain

The advent of neuroimaging techniques

In the last two decades functional neuroimaging has provided the opportunity to observe the brain "in vivo" both in normal and pathological subjects, and opened an array of new opportunities to advance our understanding of brain organisation. These techniques are, for example, positron emission tomography (PET) and magnetic resonance imaging (MRI) that is divided into structural MRI and functional MRI (fMRI). Structural MRI allows researcher to capture high-definition images of the human brain. Functional MRI allows the collection of relatively lower resolution images in rapid sequence to observe the dynamic brain response to a given stimulus.

Neuroimaging applied to language research has confirmed the classical language circuit view (Geschwind, 1970) depicted in Figure 2.1, and expanded our knowledge on new regions in the brain that are interacting in the language processing (Price, 2000). Neuroimaging techniques exploit the regional cerebral blood flow (rCBF) to demonstrate the location and the level of activity. For example, synaptic activity in a particular area of the brain requires energy. As a result, an increase in blood flow will occur. In PET scan studies, participants are injected with a mildly radioactive substance that emits positrons (i.e., positive electrons). This substance can be tracked and when it is added to glucose, which is the fuel of our brain, PET scans show which part of the brain is activated. Functional magnetic resonance imaging (fMRI) has occupied a dominant role as it provides functional images of the brain without the use of radioactive markers as in PET.

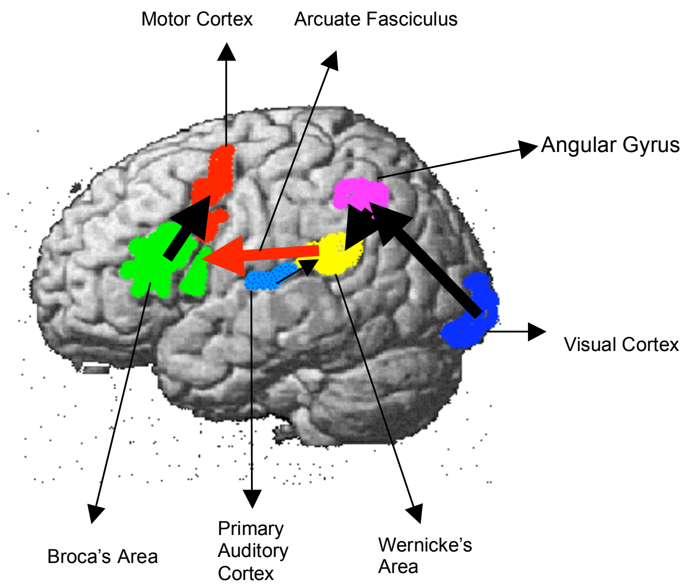


Figure 2.1: The "Classical Language Circuit Model". The anatomical location of the primary auditory cortex, Wernicke's area, the arcuate fasciculus, Broca's area and the motor cortex is related to the repetition of heard speech, whereas the visual cortex and the angular gyrus are related to reading (Geschwind, 1970).

Thus, it is a non-invasive method that indirectly measures neural activity while a person engages in cognitive tasks through the Blood Oxygen Level Dependent (BOLD) method. The assumption that underlies BOLD is that neural activation is correlated with changes in blood flow and blood oxygenation. Oxygenated and deoxygenated blood have different magnetic properties. Typically, a functional neuroimaging paradigm involves at least two associated tasks. For example, in order to study the brain area associated with the cognitive process of interest (e.g. speech comprehension) an *activation task* (e.g. listening to normal speech) should be contrasted with a *baseline task* (e.g. listening to reversed speech). The former engages the process of interest whereas the latter does not. This method is known as *subtraction methodology* and involves taking brain images during both activation and baseline conditions. The idea is that this methodology will isolate just those brain regions that are particularly relevant to performing the cognitive tasks in the experimental condition, while filtering out the activity of all those regions that are not selectively activated above baseline levels when performing the tasks. The subtraction method is widely used in fMRI studies. Another technical term in neuroimaging is *voxel*, which combines the words *volume* and *pixel*. A voxel is a 3-dimensional chunk of space, a fundamental unit of analysis into which a brain is conceptually divided up in fMRI. The size of a voxel corresponds to the spatial resolution of the fMRI imaging used in that analysis.

A relatively new approach in neuroimaging research is the one that uses structural MRI and Voxel-based morphometry (VBM, Ashburner & Friston, 2000) in the undamaged brain. VBM implies a voxel-by-voxel analysis of the whole brain with the aim to identify local morphological differences and changes in the concentration of grey or white matter (Ashburner & Friston, 2000; Mechelli et al., 2005). In a typical VBM study two groups of participants are compared (e.g., a clinical and a control group), and/or behavioural measures are correlated with differences in grey or white matter (Richardson & Price, 2009). VBM has proved valuable in advancing our understanding of experience-dependent changes in the adult brain (e.g., Mechelli et al., 2005; Richardson, Thomas, Filippi, Hearth & Price, 2009). This part will be covered in Chapter 10, where structural MRI and VBM were used with a group of late Italian/English bilinguals.

The neural correlates for cognitive control

Historically, research is this field started from neuropsychological studies of patients with frontal lobe damage. One of the most cited cases is that of Phineas Gage, the builder who miraculously survived after an iron rod passed through his head, destroying a large part of his frontal lobes. After the accident, Gage reported major changes in his personality and control of his behaviour. Thus, traditionally, there has been a strong focus on the frontal lobes. In particular, clinical and non-clinical studies have emphasised the crucial role of the prefrontal cortex (PFC) in goal-directed behaviour (e.g., Milner, 1963; Stuss & Benson, 1986). In order to execute a goal-directed action in the presence of competing information, there is the need to maintain the target information in mind, and inhibit inappropriate behaviour (Luria, 1966), a function referred to as working memory. However, brain imaging research indicated that executive functions are far more distributed across cortical and subcortical brain regions. Functional MRI used in combination with behavioural executive function tasks has revealed the specific involvement of the medial and anterior cingulate cortex (ACC) for conflict monitoring and selection among competing alternatives (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Botvinick, Braver, Barch, Carter & Cohen, 2001; Braver, Barch, Gray, Miller, Molfese, & Avraham, 2001; Bunge, Hazeltine, Scanlon, Rosen, & Gabrieli, 2002; Kerns, Cohen, MacDonald, Cho, Stenger, Aizenstein, & Carter, 2004). Interestingly, fMRI also revealed that the frontal lobes are strongly functionally interconnected with the parietal cortices. In particular, the increased activation of left parietal regions was observed in fMRI studies where participants were required to switch between tasks (e.g., Collette et al., 2005). In addition, subcortical regions of the basal ganglia, such as the caudate nuclei and the putamen, are implicated in complementary cognitive control functions (Graybiel, 1997; Middleton & Strick, 2000).

Neural correlates of bilingual language control

In an early PET study, Price, Green and Von Studniz (1999) explored language selection and switching between languages with a group of highly proficient

German/English bilinguals using a word translation task. They found that the left inferior frontal region and bilateral supramarginal gyri in the parietal cortex were more activated during switching between words from German and English. In two subsequent fMRI studies by Hernandez and colleagues (2000, 2001) a picture naming paradigm was used. Early highly proficient Spanish-English bilingual speakers were required to name a picture switching between their languages while brain activity was recorded. Two main findings were reported: (1) the use of both languages activated the same regions of the dorsolateral prefrontal cortex (DLPFC) in the left hemisphere and extended to Broca's area, indicating that Spanish and English were represented in overlapping areas of the brain, at least for the representation of words; (2) switching between languages increased activation in the dorsolateral prefrontal cortex indicating that this region, which as we saw above is associated with executive control, is involved in managing interference deriving from the alternate activation/deactivation of both languages. Hernandez et al.'s (2000, 2001) findings were replicated in another fMRI study using a word repetition paradigm within and between languages (Chee, Soon & Ling Lee, 2003). In Hernandez and colleagues (2000, 2001) work, the switching condition was pooled together, so it was not possible to establish if more or less activation was correlated with switching between L1 to L2 or L2 to L1. In a recent fMRI and PET study by Crinion and colleagues (2006), the regions involved in language control were specifically studied in two culturally different groups of bilinguals: German-English and Japanese-English participants. Using a semantic priming task, the authors demonstrated a language-dependent activation at the head of the left caudate nucleus. The activation was reduced for prime-target word-pairs that were semantically related and from the same language. However, there was more activation when these pairs were from different languages. The authors concluded that the caudate nucleus might play a fundamental role in supervising the correct selection of languages. Overall, brain imaging studies applied to bilingualism showed that regions of the executive system are associated with language selection, inhibition and switching. These results may suggest these language processes recruit domain-general high-level control functions. In a recent review, Abutalebi and Green (2007) held this position and argued that language control in bilinguals uses the same cortical and subcortical structures that are active in cognitive control and task switching in monolingual speakers. They summarised the neural correlates for language selection, inhibition, switching and translation found in fMRI studies (Price, Green & Von Studniz, 1999; Hernandez et al., 2000, 2001; Crinion et al., 2006; Rodriguez-Fornells et al., 2002, 2005; Abutalebi et al. 2007) and proposed a functional fronto-parietal-subcortical network, in which language control and executive functions are integrated. As shown in Figure 2.2, the network is characterised by four main interconnected structures: (1) the prefrontal cortex, involved in response selection, updating and inhibition; (2) the anterior cingulate cortex, involved in error detection; (3) the parietal cortices, involved in the language switching process; and, (4) the caudate nucleus and the basal ganglia, involved in supervising the appropriate language selection.

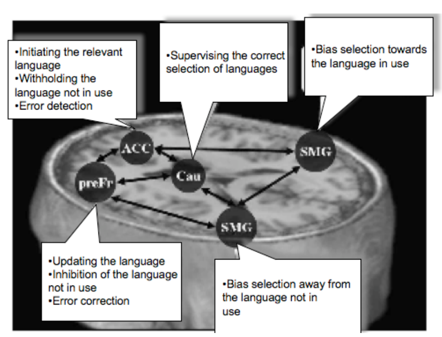


Figure 2.2: The bilingual language control network proposed by Abutalebi and Green (2007).

The aim of this thesis is to investigate how second language development affects cognitive control. More specifically, three main questions motivate this research project: (1) Does the bilingual experience enhance children's and adults' cognitive functioning? (2) How do bilinguals manage to control their two languages? (3) Will adults' brain structures change as a function of increased ability to control both languages?

In order to address these questions, a cross-sectional investigation involving early bilingual children and late bilingual adults was planned. Both behavioural and neuroimaging techniques were used to establish the impact of bilingualism early and later in life. Before presenting experimental data, Chapter 3 and 4 present a detailed description of the participants and the general methodology used in this thesis. In the following paragraphs I discuss how the three general questions are justified on the basis of the research reviewed in this Chapter.

Question 1. Does the bilingual experience enhance children's and adults' cognitive functioning?

In the literature review discussed so far I described the main components of cognitive control and the main theoretical frameworks, including a developmental perspective. I then focused on the positive effects of bilingualism in executive function, describing the paradigms and the findings from linguistic and non-linguistic tasks.

There are two main outcomes from this body of research. First, despite bilinguals showing a deficit in lexical access and tending to have a smaller vocabulary in each language than monolinguals, their understanding of linguistic structure (metalinguistic awareness) is better than that of comparable monolinguals. Second, bilingual children, young adults, and older adults outperformed age-matched monolinguals in non-verbal tasks that require controlled attention and inhibition. As negative and positive effects of bilingualism have been found within the same sample (e.g., Bialystok, Craik & Luk, 2009), it was argued that both effects might share the same origin (e.g., Bialystok, 2008). However, it was also argued that these findings may be confounded by a lack of experimental control, in particular the effect of different cultures and socio-economic status (SES). Additionally, prior work with children has not used a developmental approach and executive function abilities in both children and adults have been investigated focussing on non-verbal tasks, the visual modality or low-level auditory discrimination (e.g., Bialystok, 2008; Soveri et al., 2010). These issues are addressed in Study 1, 2, 3, and 4.

Study 1 and 2: bilinguals and monolinguals compared over development

In the first two studies I investigated linguistic and non-linguistic ability in a group of 54 early bilingual children of different cultures, and 45 age-matched monolingual peers (age range from 4 to 7-year old). I used a standardised test for vocabulary acquisition, the BPVS (BPVS II; Dunn, Whetton, & Burley, 1997), an executive function task, the Simon task (Lu & Proctor, 1995; Simon & Wolf, 1963), and a probabilistic learning paradigm (Muenke et al., 2009). Socio-economic status was assessed through parental questionnaires (see details in Chapter 3). Both studies used a developmental approach. Prior work based on aggregated data provided the dimension of a general effect, but failed to identify what degree of bilingualism can have a detrimental effect on the bilingual children's vocabulary development or pinpointing its cause. In contrast, here I aimed to assess the children's change in performance over development with both linguistic and non-linguistic tasks. Developmental trajectories were built comparing the performance of early multi-language bilingual and English monolingual children across a 3-year age range.

Study 3: exploring attention with high-level auditory stimuli

In Study 3 I aimed to extend evidence for a bilingual advantage in verbal control beyond the syllable level (Soveri et al., 2010) and word-level (e.g., Bialystok et al., 2008), to the level of sentence interpretation. For this purpose I adapted a diotic listening paradigm in order to determine whether or not there was also a bilingual advantage in sentence comprehension in the face of sentence-level interference. I compared the comprehension of simple sentences (low comprehension demand) and complex sentences (high comprehension demand) in Italian/English adult bilinguals and monolingual controls in the presence or absence of sentence-level interference.

Study 4: attention, inhibition and monitoring

As we saw in this chapter, the bilingual advantage observed in studies using visual stimuli cannot be explained only in terms of better inhibition mechanisms but expanded to other attentional processes such as monitoring and shifting. In Study 4 I extended prior work to auditory stimuli by devising a diotic listening paradigm. I compared bilingual and monolingual adults performance in attentional processing during switching simple auditory instructions in the presence of target-conflicting and target-non-conflicting language interference. I aimed to explore the bilingual ability to monitor the changes in the perceptual characteristics of the stimuli. In particular, I investigated at what level in the comprehension system a bilingual speaker is screening out a task irrelevant message.

Question 2. How do bilinguals manage to control their two languages?

The process of language selection is particularly challenging for bilinguals compared to monolinguals. As we saw in Chapter 1, there is growing evidence that both languages are active in parallel in the bilingual mind. The process of selecting and producing the appropriate word among a variety of competing lexical items in two linguistic representations requires complex cognitive control mechanisms. Current behavioural research has not yet provided sufficient evidence whether these mechanisms rely more on facilitatory processing within the lexicon (e.g., Costa, 2005) or inhibitory processing external to the lexicon (e.g., Green, 1998). In Study 5 I investigated language switching in production by extending Meuter and Allport's (1999) study with digits to word naming. Words in two different languages (English and Italian) were choosen by class (i.e., Cognates, Homographs and Singles – see Chapter 9) and balanced by frequency. I aimed to investigate switching cost asymmetry between L1 and L2, in particular if this asymmetry is modulated by word class and if the magnitude of switching cost varied with different degrees of second language proficiency.

Question 3. Will adults' brain structures change as a function of increased ability to control both languages?

As we saw in this chapter, functional brain imaging and ERP studies provided convincing evidence that language control in bilinguals uses the same cortical and subcortical structures that are active in cognitive control and task switching in monolingual speakers (Abutalebi & Green, 2007). However, to my knowledge, no study has addressed the question if these brain structures can change in relation to experience. In the last study of this thesis I investigated how the ability to control interference from the non-target language was related to long-term plasticity in brain structures. For this purpose, I used structural MRI and VBM, and correlated grey matter density of brain images acquired when bilingual participant were resting in the scanner, with their ability to control interference measured behaviourally outside the scanner (see Chapter 10).

Chapter 3

General Methodology

3.1 Introduction

Early bilingual and English monolingual children, late Italian/English bilingual and English and Italian monolingual adults took part in this research project (Table 3.1). In this chapter, participants' characteristics and methodological procedures are described. General data collection methods and analyses will also be described.

Table 3.1: Brief description of the studies and the participants who took part in this research project

Studies/Chapter	Participants	Study description
Study 1 – Chapter 5	• Early bilingual children • English monolingual children	Executive function and language skills in early bilingual children
Study 2 – Chapter 6	• Early bilingual children • English monolingual children	Probabilistic learning in early bilingual children
Study 3 – Chapter 7	• Late Italian/English bilingual adults • English monolingual adults • Italian monolingual adults	Attentional effects in language comprehension
Study 4 – Chapter 8	• Late Italian/English bilingual adults • English monolingual adults	Executive function and inhibitory control: attention to and switching between perceptual processes of speech input
Study 5 – Chapter 9	• Late Italian/English bilingual adults	Control effects in language production
Study 6 – Chapter 10	• Late Italian/English bilingual adults	MRI study: brain structural changes and control of interference

3.2 Ethics

The studies with early bilingual and monolingual children (Studies 1 and 2) were approved by the Birkbeck College Ethics Committee and entirely conducted at a primary school in West London with a high number of bilingual children. Given the great educational interest, the head teacher and her staff were eager to collaborate as they found this study highly beneficial for a deeper insight on bilingualism and cross-culture integration. Moreover, the tests administered in this study were similar to other psychometric tests in use at the school. For these reasons, an Opt-Out parental consent was permitted. All studies involving adult participants were listed under Birkbeck's ethical permission given to Dr. Frederic Dick.

3.3 Description of participants

Child participants

All participants were recruited at St Mary's of the Angels RM primary school in West London. The school was chosen for its high number of bilingual children estimated at 60% of the total number of pupils. The targeted sample for this study were children from nursery, reception and key stage 1 classes with ages ranging from 4 to 7 years old. The experimenter gave a presentation about the studies and their objectives to the school's head teacher and her staff, and the parents were sent a letter from the school informing about the studies and asking to those who did not wish their child to take part to report their decision to the secretary within 3 working days. Only one parent expressed an objection, and her child was excluded from the studies.

A total of 112 children were tested but 13 of them were subsequently excluded. Reasons for exclusion are provided in the next paragraphs. Ninety-nine children were included in the analysis. All parents were asked to complete a language history questionnaire adapted from Tokovicz, Michael and Kroll (2004) in which they indicated their children's spoken languages, their use within the family and the extended family, curricular and extra curricular activities. Parents were also requested to indicate their native language and their educational level, (i.e., 1=Primary/Elementary school, 2=High school, 3=University or higher). Additionally, for the bilingual families, it was asked if at least one parent was a native speaker of English. A copy of the questionnaire is shown in Appendix V. Twenty-three percent of the parents (14 bilingual families and 9 monolingual families) did not return a completed questionnaire. Biographical data from the questionnaires regarding both children and parents are reported in the paragraphs below. Data collection was completed between the 4th of February and the 2nd of March 2009.

Bilingual children

The parent questionnaire revealed that 10 children spoke more than 2 languages and were not included in the analysis. One bilingual child was also excluded as he could not complete all tests. Thus, 54 bilingual children were included in this study. Table 3.2 shows the bilingual children's country of origin and the languages spoken. Figure 3.1 displays the percentage of children by language. The parent questionnaire confirmed that all children were exposed to English language either from birth or before the age of three and they had a regular used of both languages, with English predominantly spoken at school and the second language spoken within the family and the extended family. Parents also reported that bilingual children could count, dream and express their feelings in both their known languages.

Table 3.2: Countries and Continents represented by the early bilingual children

Continent	Country	Language
Europe	Portugal	Portuguese
	Spain	Spanish
	Italy	Italian
	France	French
	Poland	Polish
Latin America	Brazil	Portuguese
Africa	Ethiopia	Amharic
	Eritrea	Tigrina
	Ghana	Twi
	Egypt	Arabic
Southeast Asia	Philippines	Tagalog

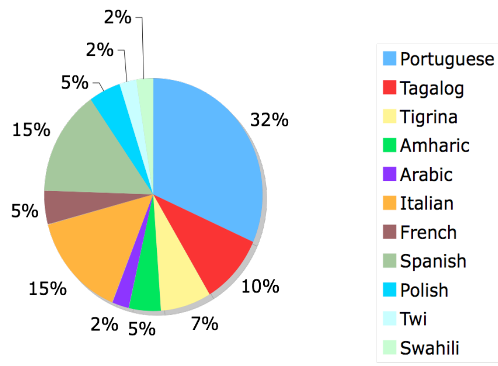


Figure **3.1:** Percentage of children by language

Monolingual children

All monolingual children were born in the UK and raised in English monolingual families. They were regularly exposed to different languages at school and had received a 1-hour-a-week lesson of Italian by a native Italian teacher since reception class. Two monolingual children were excluded from the analysis for the following reasons: (1) one child was not given permission from his parents to perform the tasks; (2) one child could not complete all tasks. Thus, 45 English monolingual children were included in this study.

Parents

Data from the completed language history questionnaires revealed that 40% of bilingual families had at least one parent who spoke English as first language. Within those families, 31% of the fathers and 10% of the mothers were native English speakers. All parents in monolingual families were native English speakers.

Averaged parental educational level scores ((i.e., 1=Primary/Elementary school, 2=High school, 3=University or higher), revealed that bilingual and monolingual parents had a comparable education, mean=2.61 (SD=0.46) for bilingual parents and mean=2.65 (SD=0.49) for monolingual parents, and levels of education were equally distributed, $\chi^2(2)=1.33$, *n.s*. The mothers' and fathers' level of education is reported in percentage in Table 3.3.

Table 3.3: Bilingual and monolingual parents' educational level (%)

	Primary		**Secondary**		**University degree or higher**		**N/A**	
	Father	Mother	Father	Mother	Father	Mother	Father	Mother
Monolinguals	8	-	19	25	58	61	14	14
Bilinguals	3	3	33	28	53	58	13	13

Adult Participants

There were three adult groups in this research project: (1) bilinguals; (2) English monolinguals; and, (3) Italian monolinguals. The three groups performed study 3, whereas study 4 compared bilinguals and English monolinguals. Only bilinguals took part in studies 5 and 6. Participants were recruited either in London or in Italy according to their language group. They all had normal or corrected to normal vision, normal hearing and no reported neuro-pathologies. Participants' mean age, age range, standard deviation and gender are summarised for each study in Table 3.4.

Table 3.4: Participants' age and gender details and studies where they took part

Study	Language Group	N	Age (SD)	Age Range	Sex
3	Bilinguals	20	32 (6.3)	20-41	9 M
	English Monolinguals	20	32 (6.6)	24-55	8 M
	Italian Monolinguals	20	30 (10)	19-49	10 M
4	Bilinguals	17	31.5 (7.5)	21-42	4 M
	English Monolinguals	17	33.3 (9.1)	20-55	6 M
5	Bilinguals	20	34 (6.6)	21-46	11 M
6	Bilinguals	27	33 (7)	21-41	10 M

Bilingual adults

Thirty-seven Italian adults who were exposed to English at different times in their lives were chosen from a variety of professional settings (see paragraph 3.4 for details) through formal announcements, that is, adverts affixed at the Italian Book Shop, the Italian Institute of Culture, and Birkbeck College in London, or through word-of-mouth. They all completed a questionnaire adapted from Li, Sepanski and Zhao (2006). The questionnaire is shown in Appendix IV. Their age ranged from 21 to 46 years old. They all had formal education in Italy and moved to the UK later in adulthood except for one who was raised in England but had Italian parents. This early bilingual participant took only part in Study 6. All bilingual participants self-rated their competence in English in 4 language dimensions on a scale ranging from 1 (very poor) to 6 (native like). All of them reported good competence of English in all dimensions, with a 4.9 mean score for reading ability (SD=0.7), 4.5 for writing ability (SD=0.9), 4.4 for speaking ability (SD=0.9), and 4.5 for listening ability (SD=0.9). On this basis, they were all admitted to take part in the study. Occasionally, bilinguals reported that they had been exposed to a third or a fourth language; 23 of them (62% of the total) reported being exposed to a third language but only 9 of them rated themselves as fluent. The majority of bilingual speakers (87%) reported switching between their known languages during conversation. The bilinguals' background data from the language history questionnaire are reported in Table 3.5.

Table 3.5: Bilinguals' language history and studies in which they took part (grey cells).

Sub.	Age	Sex	Studies in which they took part				Age of		Tot. years in the UK	Exposed to more than 2 languages	Switch
			3	4	5	6	L2 first Exposure	Arrival in the UK			
1	40.7	F	■	■	■	■	15	29.7	11	Y	Y
2	37.7	M	■		■		10	26.7	11	Y	Y
3	31.1	M	■		■	■	24	19.1	12	Y	N
4	32.5	M		■		■	12	22.5	10	N	Y
5	28.7	M			■		14	26.7	2	N	Y
6	40.1	F			■		12	29.1	11	Y	Y
7	34.6	F	■	■	■	■	13	22.6	12	Y	Y
8	21.3	F	■		■	■	10	19.3	2	N	Y
9	28.1	F	■				2	14.9	10	Y	Y
10	24.9	F		■		■	6	27.1	1	Y	Y
11	38.1	M	■		■	■	7	34.1	4	Y	N
12	20.2	M	■		■	■	5	18.2	2	Y	Y
13	30.8	F	■				6	27.8	3	N	Y
14	21.1	F		■		■	19	19.1	2	Y	Y
15	31.4	M	■		■	■	10	30.4	1	Y	N
16	46	F				■	0	0.0	46	N	Y
17	41.5	F		■		■	6	40.5	1	Y	N
18	35.7	M	■		■	■	4	19.7	16	Y	Y
19	33.2	M	■				11	31.2	2	N	Y
20	40.2	F		■		■	12	25.2	15	N	Y
21	35.8	M		■	■	■	12	23.8	12	Y	Y
22	36.5	F	■	■		■	11	35.5	1	N	Y
23	22.4	M	■	■		■	10	21.4	1	Y	Y
24	29.1	M				■	12	28.1	1	N	Y
25	40.1	F	■				12	39.1	1	N	Y
26	40.4	F		■		■	4	24.4	16	Y	Y
27	38.7	F	■	■	■	■	11	37.7	1	Y	Y
28	25.1	F	■		■	■	11	18.1	7	N	Y
29	28.2	F		■		■	17	17.2	11	Y	Y
30	34.8	F	■		■	■	9	33.8	1	Y	Y
31	28.2	F		■		■	11	25.2	3	N	Y
32	25.6	F	■	■	■	■	12	22.6	3	Y	Y
33	38.8	F		■	■	■	10	24.8	14	Y	Y
34	45.8	M			■		12	33.8	12	N	N
35	22.4	F		■			6	21.4	1	Y	Y
36	30.2	M			■	■	7	29.2	1	Y	Y
37	34.6	M	■		■		7	32.6	2	N	Y

English monolingual adults

Twenty English monolinguals of age ranging from 23 to 55 were recruited and tested in London, mainly from Birkbeck College's various departments. Some of them occasionally reported exposure to a second language although never reaching a proficient level of fluency. None of them was regularly exposed to or had formal education of Italian language.

Italian monolingual adults

Twenty Italian monolinguals of age ranging from 19 to 49 were recruited and tested in Livorno. The town of Livorno is located on the Italian West coast in Tuscany, a region in Italy in which the local population does not speak any dialect. The language in use is therefore Italian, although there are subtle regional inflections. All Italian monolinguals were exposed to English in their adolescence as English was taught as a second language in secondary school. However, none of them reported a daily use of English.

3.4 Participants' educational level and socio-economic-status classification (SES)

All participants provided their level of education and their professions. Occupations were classified according to the Standardised Occupational Classification 2000 (Office of National Statistics, 2004) and shown in Table 3.6. Education levels are reported in Table 3.7.

Table 3.6: Classification of participants' Socio-Economic Status (SES). Numbers show percentages.

SES	**Bilinguals**	**English Monolinguals**	**Italian Monolinguals**
Managers and senior officials	13	0	5
Professional occupations	26	30	30
Associate professional & technical occupations	3	0	0
Administrative and secretarial occupations	5	50	10
Skilled trades occupations	8	0	20
Personal service occupations	5	0	0
Sales & customer service occupations	8	0	0
Unemployed (students included)	32	20	35

Table 3.7: Details of participants' education level. Numbers show percentages.

	Bilinguals	English Monolinguals	Italian Monolinguals
A-Level or equivalent	14	5	40
BSc or equivalent	27	40	50
Post grad. (MSc, PhD) or equivalent	59	55	10

3.5 Stimuli and Apparatus

Stimuli

Different visual and auditory stimuli were used according to the paradigm in use. They are described in the relevant experimental chapters. Standardised tests are described in Chapter 4.

Apparatus

All experiments were run on the same MacBook laptop and presented on a 14" monitor. Stimulus presentation was controlled using Matlab R2008b v.7.7. Other input/output devices used in the studies are detailed in the relevant chapters.

3.6 General Procedure

Children

All children were tested at the school, in a quiet room made available by the head teacher. Each child was tested in two separate sessions of about 15 minutes each. Children were allocated either to the first or the second session, which were both completed within 7 days. Each child was randomly taken from their class in agreement with their teacher and accompanied to the test room. The experimenter took particular care in greeting the children and put them at ease. At the end of each session, the child was given a sticker as a reward. All children were also given a certificate stating their participation in the studies as "*Child Scientists*". The school was given book vouchers for a total value of £200.

Adults

The majority of the bilingual speakers participated to all the studies (Studies 3, 4, 5 and 6). However, due to relocation or unavailability at the moment of testing, some of them could not take part in all the studies. For study 3 and 4, they were tested in a quiet environment either at the Birkbeck's Centre for Brain and Cognitive Development or at their own premises. For study 5 (behavioural part) they were uniquely tested at the Centre for Brain and Cognitive Development. MRI scans (study 6) were all performed at the UCL Wellcome Trust Centre for Neuroimaging.

Monolingual speakers only took part in studies 3 and 4 as group controls. English monolinguals were tested either at their premises or at the Centre for Brain and Cognitive Development. Italian Monolinguals were tested in Livorno, Italy. All adults were given a reimbursement of about £8 for each hour of testing (€5 for the Italian monolinguals).

3.7 Conclusions

In this chapter I described the participants, both children and adults, who took part in this research project. In the next chapter I will describe the linguistic and non-linguistic standardised tests I used in the study.

Chapter 4

Standardised tests

4.1 Introduction

In this chapter I will describe the standardised tests used in the research project. Other non-standardised behavioural measures and neuroimaging paradigms will be described in the relevant chapters. A complete list of the standardised tests is displayed in Table 4.1.

Table 4.1: Standardised tests description and studies in which they were used

Study	Task	Description
Study 1	Coloured Raven's Matrices	Standard non-verbal reasoning test
Study 1	British Picture Vocabulary Scale (BPVS)	British English Standard Receptive Vocabulary Test
Study 3, 5 and 6	Bilingual Verbal Ability Tests (BVAT)	Standardised test to assess bilingual verbal ability and a measure of English language academic proficiency.
Study 6	Matrices (Subtest of the British Ability Scale, BAS II)	Standard Non-Verbal Reasoning Test

4.2 Tests to assess linguistic ability

The Bilingual Verbal Ability Tests (BVAT)

The Bilingual Verbal Ability Tests (BVAT - Muñoz-Sandoval, Cummins, Alvarado, & Ruef, 1998) is a standardised test to assess bilingual verbal ability. The BVAT is available in 18 different languages, including most Indo-European and Asian languages. The BVAT contains three tests administered individually: (1) Picture Vocabulary; (2) Oral Vocabulary; and (3) Verbal Analogies.

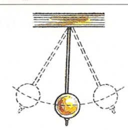
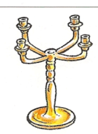
In the Picture Vocabulary test, the subject is required to name a total of 58 pictured objects with the degree of difficulty increasing gradually. It is an expressive language task that involves word retrieval ability at the single word level and measures comprehension/knowledge. The Oral Vocabulary is divided in two subtests, one for Synonyms (20 items) and one for Antonyms (24 items). In the Synonyms subtest, the subject is required to make a synonymous word association with difficulty increasing gradually. This task measures knowledge of word meanings during an oral presentation of stimuli. In the Antonyms subtest, the subject is required to make an opposite (antonymous) word association with difficulty increasing gradually. This task measures knowledge of word meanings during an oral presentation of stimuli. In the Verbal Analogies test, the subject is required to recognize the analogous relationships between two words and to find a word that fits the same relationship to a third word. This task, consisting of 35 items, measures verbal reasoning in increasingly more complex conceptual/logical. An example of the BVAT's stimuli is shown in Table 4.2.

All tests are administered in English first. Each item failed in English is re-administered in the native language. This leads to two different scores: (1) an English raw score; and (2) a gain score for L1. All scoring is automated through the "Scoring and Reporting Program" software, which is a standard feature of the BVAT kit.

In this research project the BVAT was used to assess the level of proficiency in English in late bilingual adults. To my knowledge, the BVAT is the only standardised test available that can generate a measure to assess lexico-semantic abilities in L2, the cognitive-academic level of proficiency (CALP). This more refined evaluation of the individual's level of proficiency makes a distinction from basic interpersonal communicative skills (BICS). The distinction was intended to draw attention to the very different time periods typically required by second language learners to acquire conversational fluency as compared to grade-appropriate academic proficiency in that language. Conversational fluency is often acquired to a functional level within about two years of initial exposure to the second language, whereas more time is usually required to catch up to native speakers in academic aspects of the second language (Collier, 1987; Cummins, 1981; Klesmer, 1994).

The CALP was used as a covariate in Study 3, 4, 5 and 6. The CALP is expressed in five levels of English language proficiency, from negligible through very limited, limited, fluent to advanced.

Table 4.2: An example of the BVAT tests. Possible correct answers are indicated in brackets.

Picture Naming	Synonyms	Antonyms	Verbal Analogies
	Near *(Close)*	Boy *(Girl)*	bird...flies, fish... *(swims)*
	Big *(Huge)*	Large *(Small)*	hungry...eat, tired... *(sleep)*
	Nap *(Sleep)*	Soft *(Hard)*	coat...wear, apple... *(eat)*
	Untamed *(Wild)*	Old *(Young)*	cut...hair, mow... *(lawn)*
1) Sphinx *2) Pendulum* *3) Loom* *4) Candelabra*	Portion *(Part)*	Accumulate *(Lose)*	water...pipe, electricity... *(wire)*
	Devour *(Eat)*	Attract *(Repel)*	refrigerator...zoo, food... *(animal)*
	Conceal *(Hide)*	Serene *(Agitated)*	wine...vat, water... *(tank)*

British Picture Vocabulary Scale (BPVS)

The British Picture Vocabulary Scale (BPVS II; Dunn, Whetton, & Burley, 1997) is a standardised measure of English receptive vocabulary in which participants are shown slides with 4 pictures and asked to indicate the picture most associated with the word read out by the experimenter. An illustration of the test is shown in Figure 4.1.

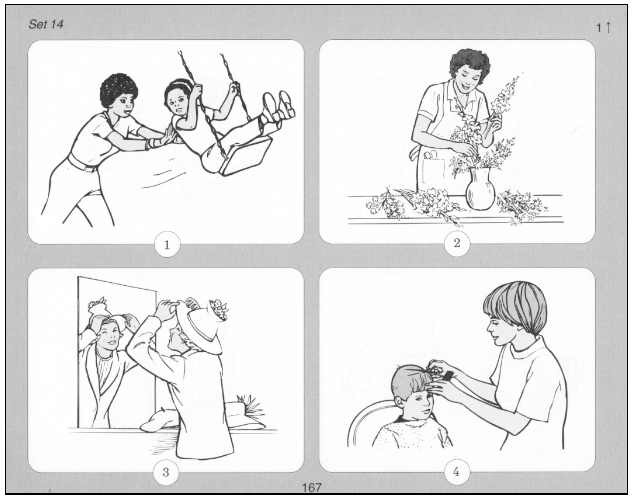


Fig 4.1: A BPVS plate. Here the experimenter says the word *Tonsorial*. The participant has to indicate the figure that goes with what the experimenter says, in this case figure no. 4.

The BPVS consists of 14 sets of words of increasing levels of difficulty, each containing 12 items. Each set has an approximate age-range indicator, which is used to select the appropriate starting point of the test. The *base* set is established when the participant makes no more than one error on the initial set. If more than one error is made, preceding sets are administered until a base set is determined. The *ceiling* set is established when the participant makes eight or more incorrect responses within a set. The test score is calculated by subtracting the total errors made from the item number of the ceiling set. The BPVS' ability scores were used to assess linguistic competence between early bilingual and English monolingual children (Study 1).

4.3 Tests to assess non-verbal ability

Matrices (Part of the British Ability Scale II)

The Matrices task from the BAS-II (BAS-II; Elliot, Smith, & McCulloch, 1997) is a test of non-verbal visuospatial ability that was used as a stand-in for performance IQ. In this test, participants are shown an incomplete matrix of black and white abstract figures, with each matrix consisting of either four or nine cells. Participants are required to select the most appropriate pattern to complete the matrix from six potential tiles by pointing to or reading the number of the tile that best completes the matrix, as displayed in the example in Figure 4.2.

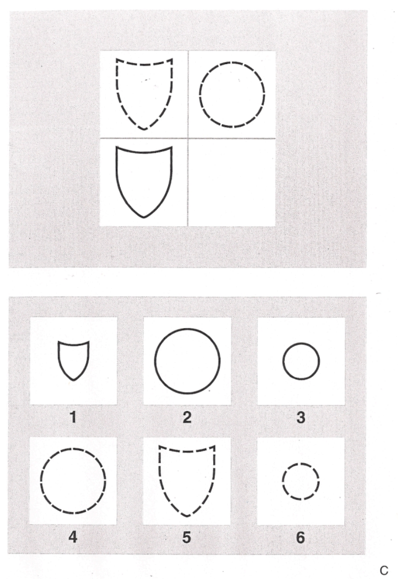


Figure 4.2: Example of the Matrices test: subjects are required to identify one of the 6 items proposed below, in order to complete the quadrant left blank above. In this case the right answer is no. 2.

Participants first complete four practice items and then begin the test at an age-appropriate level, which is indicated on the test (previous items are administered should they fail on the first three test items). The test is discontinued if the participant makes five failures out of six consecutive items. An ability score, which takes into account the number and the level of difficulty of the test items completed, is then obtained from a look-up table supplied with the test. The Matrices' ability scores were used as a covariate in the neuroimaging study with adult late Italian/English bilinguals (Study 6).

Coloured Raven's Matrices

The Raven's coloured matrices (Raven, Court, & Raven, 1986) were used with early bilingual and English monolingual children to assure that all of them had similar intellectual abilities (Studies 1 and 2).

This test consists of 36 items divided in 3 sets of 12 (A, Ab, and B), arranged in order of difficulty. As shown in the example in Figure 4.3, each item contains a picture with a missing part. Below the picture, there is a multiple choice of 6 possible parts to complete the picture. Only one of these parts fits with the missing part in the picture.

Children were given a score for each correct answer, and their score were converted into standardised ranks according to a table based on the children's age.

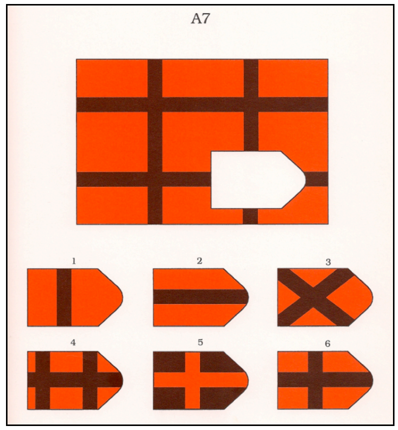


Figure 4.3: An example of the Coloured Raven's Matrices in which the child is required to choose one of the 6 items proposed below in order to complete the blank space in the picture above. In this case the right answer is no. 6.

4.4 Conclusions

In this chapter I have described all the standardised tests that were used in this research project. Some of them measured verbal abilities (i.e., the BVAT and the BPVS), and others measured non-verbal abilities (i.e., the Matrices, and the Raven's Coloured Matrices). In the next chapter, *Executive function and language skills in early bilingual children*, I used the BPVS and the Raven's Coloured Matrices in order to assess English receptive vocabulary and intellectual ability in bilingual and English monolingual children from age 4 to 7 years old.

Chapter 5

Study 1: Executive Function and language skills in early bilingual children

5.1 Introduction

Does bilingualism cause educational or cognitive disadvantage to children? Does the bilingual experience enrich children's cognitive development? These two questions are at the centre of one of the most intriguing debates in psycholinguistics and a matter of concern for parents and educators.

As discussed in Chapter 1, early research highlighted the negative aspects of bilingualism. Up to the 1960s it was generally believed that bilingualism was a cause for delay in the child's cognitive development (e.g., Hakuta & Diaz, 1985, for a review). These ideas started to dissipate since following the publication of a study by Peal and Lambert (1962) that showed a general advantage of bilinguals over monolinguals in a wide range of tests measuring aspects of school achievements. Recent research has been more balanced, trying to identify areas in which bilingual children may show a disadvantage and others where they may have an advantage over monolinguals.

Bilingual advantage in executive function

One of the most striking claims of the last few decades is that bilinguals have an ability to suppress irrelevant information not only in the language domain, but also in other areas that require non-linguistic central inhibitory functions. Two executive function paradigms in particular have been used in bilingual research: (1) the Dimensional Change Card Sorting Task (Zelazo, et al. 1996), and; (2) the Simon task (Lu & Proctor, 1995; Simon & Wolf, 1963). Both tasks were described in Chapter 2. Bialystok and colleagues, (1999, 2004) used the DCCS task to compare the performance of 3 to 5-year-old monolingual and bilingual children. The results showed that bilinguals outperformed monolinguals in inhibiting the previously learned rule and shifting into the new one (Cohen's *d*=0.73). The authors concluded that early bilingualism had a positive effect on the development of executive functioning. Moreover, Bialystok, Martin and Viswanathan (2005) provided additional data in support of a more efficient development of inhibitory processing in bilinguals using the Simon task (Lu & Proctor, 1995; Simon & Wolf, 1963). The results showed that 5-year-old bilinguals had faster reaction times than monolinguals on both congruent and incongruent trials (Cohen's *d*=0.9), although the groups did not differ in terms of accuracy. The current interpretation of this advantage is that the constant use of two languages adds cognitive flexibility in bilingual children (Bialystok, 2008).

However, Morton and Harper (2007) questioned the robustness of Bialystok's work as they reported inconsistent data using the Simon Task with 6-7-year-old monolingual and bilingual children. The task was designed identically on Bialystok's task (Bialystok et al. 2004, Experiment 1) and used the same number of participants, that is, 17 bilingual and 17 monolingual children from 6 to 7-year-olds. Although participants were faster and more accurate with congruent than incongruent trials, the authors found no difference between the two language groups on the Simon task. A further correlation analysis revealed that better performance was not related to language knowledge but rather to socio-economic status (SES), $r= -35$, $p<.05$; $\rho=0.35$, indicating that children from higher SES families showed a smaller cost of conflict in the Simon task in terms of errors. In a commentary article Bialystok (2009) claimed that Morton and Harper's (2007) whole experimental design and logic was weak and the correlation between the Simon task and SES was moderate. Moreover, she expressed some concerns about the methodology used. Morton and Harper (2009) replied that their study was not originally designed to investigate SES effects on executive function, but SES was used only as a control measure. They also pointed out that their methods were comparable with Bialystok's, and concluded that a possible bilingual advantage in cognitive control should be investigated further (Morton & Harper, 2009).

Bilingual disadvantage in vocabulary acquisition

As discussed in Chapter 2, some negative aspects of bilingualism are also reported in the current literature. In particular, bilingual children seem to develop vocabulary more slowly in each language than monolingual speakers within each language (e.g., Bialystok & Feng, in press; Oller & Eilers, 2002). Although converging developmental data show that bilingual children who have been regularly exposed to two languages from early life achieve the same general linguistic milestones as monolinguals do (De Houwer, 2005; 2009), they are often reported below the norm when compared to monolingual children in terms of vocabulary acquisition. Bialystok and Feng (in press), for example, routinely administer a standard test measuring receptive vocabulary in English, the Peabody Picture Vocabulary Test, PPVT-III (Dunn & Dunn, 1981). Combining the results of 16 different studies (N=963, approximately half bilinguals), the authors found that monolingual children from 5 to 9 years old outperformed their bilingual peers at all observed ages (Cohen's $d = 0.8$).

The rationale for this study

Aggregate data studies, although providing the dimension of a general effect, are of little use to identify what degree of bilingualism can have a detrimental effect on the bilingual children's vocabulary development or pinpointing its cause. For example, children with limited proficiency in the language of schooling are reported to experience increased difficulty in coping both academically and socially (Bialystok, McBride-Chang & Luk, 2005). Another example discussed above comes from the work of Morton and Harper (2007) who showed that possible cognitive advantages in executive function were not related to bilingualism, but rather to socio-economic status (SES). It is therefore essential to control for individual differences such as children's background, language proficiency and parental SES, in order to identify possible disadvantages and understand what kind of intervention is required.

The main goal of this cross-sectional study was not to compare children's performance in all tasks by their age group, rather to assess how linguistic and non-linguistic abilities change over development, in this case, a 3-year age range. For this purpose, developmental trajectories were built comparing the performance of early multi-language bilingual and English monolingual children from the age of 4 to age of 7 years. The developmental trajectory approach in cross-sectional designs has been successfully used in studies comparing the development of typically and atypically developing children (Annaz, Karmiloff-Smith, Johnson & Thomas, 2009; Karmiloff-Smith, Thomas, Annaz, Humphreys, Ewing, Brace, et al., 2004; Thomas, Grant, Barham, Gsödl, Laing, Lakusta et al., 2001; Thomas, Annaz, Ansari, Serif, Jarrold & Karmiloff-Smith, 2009).

A standard measure for English receptive vocabulary, the BPVS II (Dunn, Whetton & Pintilie, 1997), a U.K. test equivalent to the American PPVT II, was used to compare bilingual and monolingual children's linguistic skills. The Simon task was used to compare the two language groups' executive functioning. A control measure, the Raven's Coloured Matrices (Raven, Court, & Raven, 1986), was used to assess if all children had similar intellectual ability.

Three main questions were addressed in this study: (1) will early multi-ethnic bilingual children show a different developmental trajectory of vocabulary development when compared with age-matched monolingual children?

(2) Will the exposure to two languages since birth enhance cognitive control in non-verbal ability through development?

(3) Following Morton and Harper (2007), will a measure of SES (i.e., parental education) account for a reliable amount of variance in both verbal and non-verbal tasks?

For the purposes of this study, it was assumed that bilingualism per se was the causal factor that might modulate vocabulary size and executive function skills and therefore that, given approximately homogeneous degrees of proficiency in their language pairs, a range of language pairs would be appropriate to address these research questions.

Predictions

On the basis of previous findings, it was predicted that monolinguals will outperform bilinguals in the acquisition of English vocabulary. It was also predicted that bilinguals will outperform monolinguals in an executive function task and this advantage will be visible early in development and will remain stable throughout the trajectory, regardless of parental SES.

5.2 Methods

Participants

Ninety-nine children took part in this study, 54 were multi-language early bilinguals (mean age 66.7 months, SD=8.3, range 48.0-81.0, 27 males) and 45 English monolinguals (mean age 66.6 months, SD=9.9, range 49.0-82.0, 19 males). More biographical information on the children can be found in Chapter 3.

Tasks and Procedure

Children were tested individually in a quiet room adjacent to their classroom. Each child was greeted and asked if he/she agreed to play a computer game and answer some questions about pictures. All children gave their verbal consent. Before starting the task, the experimenter showed the children four coloured laminated squares: Green, Yellow, Blue and Red. Children were asked to identify each colour to ensure that there was no colour blindness. No children showed any difficulty. At the end of the session, the children were given a choice of stickers as a reward for their participation and were accompanied back to their classroom (see more detail in Chapter 3).

Tasks included the Simon Task and two standard tasks, one measuring receptive vocabulary, the British Picture Vocabulary Scale (BPVS II; Dunn, Whetton, & Burley, 1997), and one measuring non-verbal intellectual ability, the Coloured Raven's Matrices (Raven, Court, & Raven, 1986). There were two testing sessions of approximately 15 minutes each (see more detail on the standardised tasks in Chapter 4).

Simon Task

A computer-based version of the Simon task was developed with Matlab and presented on a MacBook laptop. A two-button keypad was connected to the computer. A red sticker was applied to the left button and a blue one on the right button. Children were told to put both hands on the keypad and instructed to press either a red or a blue button as quickly and accurately as possible, when they saw a square of the same colour appearing on the screen. As shown in Figure 5.1, the task began with a fixation cross in the center of the screen, which remained visible for 800 ms and was followed by a 250-ms blank interval. At the end of this interval, a red or blue square appeared on the left side of the screen and remained on the screen for 2000 ms if there was no response.

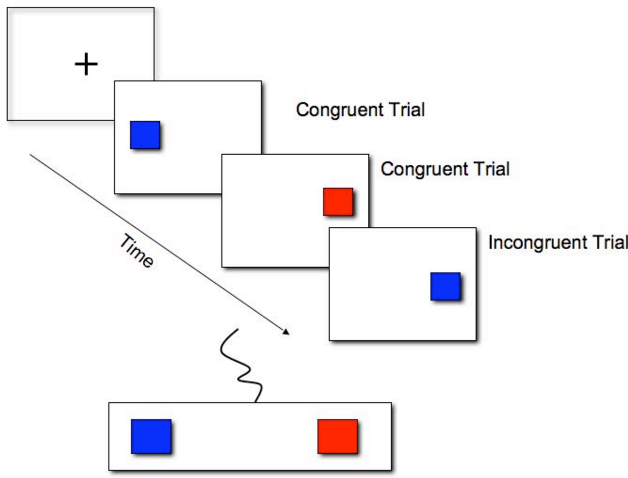


Figure 5.1: An illustration of the Simon Task. Children were required to press the left button as fast as they could when a red squared appeared on the screen and to press the right button when the blue square appeared on the screen.

Trials were defined as *Congruent* if the colour stimulus matched the side of the button (e.g., red square appearing on the left side of the screen, left button (red sticker) to be pressed), and *Incongruent*, when the colour stimulus did not match the side of the button (e.g. red square appearing on the right side of the screen, left button (red sticker) to be pressed). There were in total 4 practice trials and 28 sequential randomised test trials, 14 Congruent and 14 Incongruent. Access to the test trials was automatically given after the 4 practice trials were successfully passed. Between the practice and the test phase, all children were reminded to press the buttons as fast and accurately as they could. Five children needed more than 4 practice trials before carrying out the test. The test took approximately 5 minutes to complete.

British Picture Vocabulary Scale (BPVS)

See Chapter 4 for a full description of the task.

Raven's Coloured Progressive Matrices

The Raven's coloured matrices (Raven, Court, & Raven, 1986) were used as a control measure to assure that all of them had similar intellectual abilities (Bialystok et al. 2004). A full description of the task was provided in Chapter 4.

Language History Questionnaire

All parents were asked to complete a questionnaire in which they indicated their own and their spouse's/partner's country of origin, if at least one of them was a native speaker of English, and their highest educational level. The parental levels of education scores are reported in Chapter 3. All parents' education scores were averaged to create a SES score. For the bilingual families, it was asked if English was the native language of at least one parent and, if that was the case, those families were scored 1 point, otherwise 0.

These scores were used as covariates to assess the impact of parental education and regular use of English on the children's linguistic and cognitive abilities. More biographical data about the children and the parents were reported in Chapter 3.

5.3 Results

The main results are provided in two sections, one for vocabulary and one for executive function trajectories. A third section then considered the predictive role of SES. Statistical analyses were carried out with SPSS 16.0 for Mac. The bilingual and monolingual children's means and standard deviations in all tasks are reported in Table 5.1.

A one-way between-subjects analysis of variance (ANOVA) was carried out to assess if bilingual and monolingual children had similar intellectual ability. Analysis on the Raven's Coloured Matrices Ability scores as a dependent variable revealed a non-significant difference between the bilingual and monolingual children, $F(1,97)=.011$, $p=.917$. This result indicated that the groups had comparable intellectual abilities.

Table 5.1: Bilingual and monolingual children's performance (means and standard deviations) in the receptive vocabulary (BPVS), and non-verbal ability (Raven's Coloured Matrices) tasks.

	Bilinguals		**Monolinguals**	
N	54		45	
BPVS Standard score	98.50	*(1.67)*	104.58	*(0.78)*
Coloured Raven's Matrices Ability score	16.15	*(1.47)*	16.27	*(0.83)*

Receptive vocabulary: Will early multi-ethnic bilingual children show a different developmental linguistic trajectory when compared with age-matched monolingual children?

A between-subjects one-way ANOVA, revealed that the difference between the two groups was significant, $F(1,97)=7.183$. $p=.009$, although effect size was not large, Cohen's $d=0.5$. The results could be interpreted as a bilingual disadvantage in acquiring English vocabulary over monolinguals. Cross-sectional trajectories were built to assess the development of English vocabulary in both groups. Figure 5.2 depicts the performance of each group with the BPVS in terms of test age (TA) plotted against increasing chronological age (CA). The solid lines indicate a best-fit regression through each group's data. A linear regression is represented by an intercept and a gradient. Differences in intercepts correspond to variations in the onset of development while differences in gradient correspond to slower or faster rates of development. R^2 values indicate the proportion of variance explained by each trajectory. All trajectories were checked for outliers with Cook's distance (Cook & Dennis, 1977) to determine whether a particular data point alone affected regression estimates. No data point in all trajectories was close to or greater than 1. This indicated that the models were not unduly influenced by outliers.

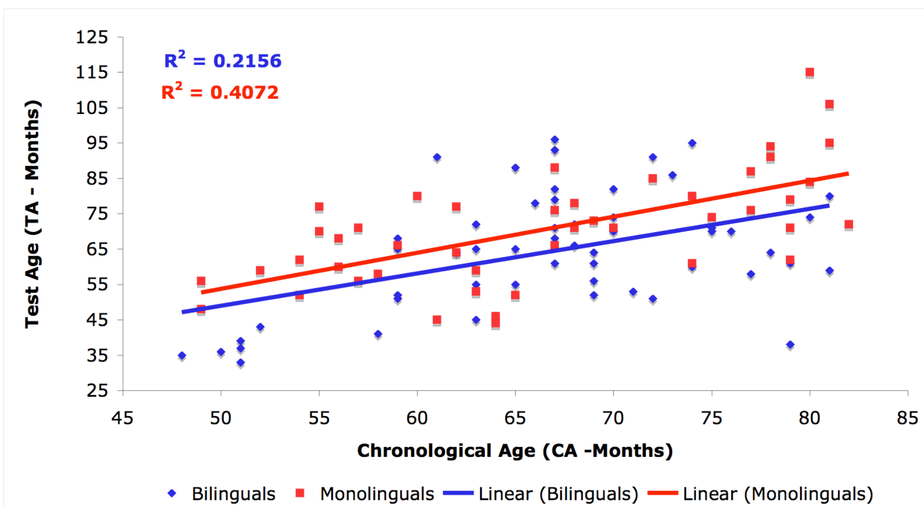


Figure 5.2: Developmental trajectory for English language acquisition in 54 bilingual and 45 monolingual children, ranging from 48 to 82 months of age

Mixed-design analysis of covariance (ANCOVA) revealed that the trajectory accounts for 33% of the total variance ($F(3,95)=15.283$, $p<.001$, $\eta^2=.326$). There was no significant main effect of language group, F(1,95)=.511, p=.477, η^2=.005, indicating that the intercepts of the two groups are similar (intercept monolinguals: 51.6; [31.9, 73.3]; intercept bilinguals: 47.1; [38.5, 56.3][1]). Thus, bilinguals and monolinguals' performance starts approximately at the same level. With the groups combined, there was a significant main effect of age, F(1,95)=39.800, p<.001, η^2=.295, revealing that bilinguals and monolinguals' chronological age is a reliable predictor of increase in performance in both groups. A non-significant interaction between group and age, F(1,95)=.115, p=.736, η^2=.001, indicated that despite the fact that the bilingual trajectory runs below the monolingual one, bilinguals and monolinguals' English language acquisition was comparable (gradient monolinguals: 1, [-.51, .71]; (gradient bilinguals: .92, [.47, 1.4]). In summary, bilingual children exhibited a normal pattern of development on the BPVS test. However, Figure 5.2 indicated that the bilingual trajectory explained less of the variance than monolingual, indicating that differences were not uniform across age. To examine this effect, the data were split into quartile age ranges and a 1-way ANOVA was carried out in each one of them. Younger bilinguals in the first quartile from 48 to 56 months of age (bilinguals=9; monolinguals=11) and older bilinguals in the fourth quartile from the age of 74 to 82 months of age (bilinguals=12; monolinguals=15) were reliably different from monolingual peers, F(1,14)=37.605, p<.001; F(1,26)=8.434, p=.008, respectively, and the effect sizes were large (Cohen's *d*=2.6 and 1.1). These differences survived a Bonferroni correction for multiple post-hoc comparisons. However, the bilingual children in the second quartile 2 from the age of 57 to 65 months and the third quartile from 66 to 73 months (N=36 in total), were not different from monolinguals (N=23 in

[1] 95% confidence intervals = [x, y]

total), $F(1,27)=.483$, $p=.493$ (Cohen's d=0.18); $F(1,28)=.706$, $p=.408$ (Cohen's d=0.22), respectively. For the current data, then, the overall group difference in receptive vocabulary stemmed from different developmental trajectories in bilingual and monolingual children, with an early and a late disadvantage for the bilingual children, but no difference in the mid range of the ages considered.

Will early bilingual children show a cognitive control advantage over monolinguals in the Simon Task?

Median reaction times were computed to reduce the influence of outliers, given that children's speeded responses are often more vulnerable to such effects. The median reaction times and the mean percent accuracy in the Simon task were initially analysed considering language group, bilinguals vs. monolinguals, regardless of age. Reaction times (RTs) and accuracy rates for both congruent and incongruent trials are shown in Table 5.2.

The RTs and accuracy rates collapsed over age were analysed with a two-way ANOVA for language group and trial type. With the groups combined, congruent trials were processed 0.11 second faster and 6% more accurately than incongruent trials, reaction times: $F(1,97)=60.646$, $p<.001$, $\eta^2=.385$; accuracy: $F(1,97)=22.368$, $p<.001$, $\eta^2=.187$. There was no effect of language group on reaction times: $F(1,97)=.002$, $p=.963$, $\eta^2=.001$ or accuracy: $F(1,97)=.081$, $p=.776$, $\eta^2=.001$, and no language group and trial type interaction in reaction times: $F(1,97)=.243$, $p<.623$, $\eta^2=.003$ or accuracy: $F(1,97)=1.587$, $p=.211$, $\eta^2=.016$. Overall, there was no evidence for a bilingual difference in response time and accuracy in the Simon Task.

Table 5.2: Means and standard deviations (in brackets) for reaction times (RT) and accuracy (CR) in the Simon Task by language group.

	Bilinguals			Monolinguals		
	N	Congruent	Incongruent	N	Congruent	Incongruent
	54			45		
RT (secs) – SD		0.80 *(0.04)*	0.93 *(0.03)*		0.81 *(0.03)*	0.92 *(0.03)*
CR (%) – SD		92 *(0.02)*	84 *(0.02)*		89 *(0.02)*	85 *(0.02)*

A developmental trajectory was built considering the children's performance with the most demanding condition, that is, with incongruent trials. As displayed in Figure 5.3, the trajectory shows the performance of each group in terms of reaction times (RTs in seconds) plotted against increasing chronological age (CA). RTs sometimes display a non-linear relationship to age. However, in this case, a logarithmic transformation of the data did not provide a better fit.

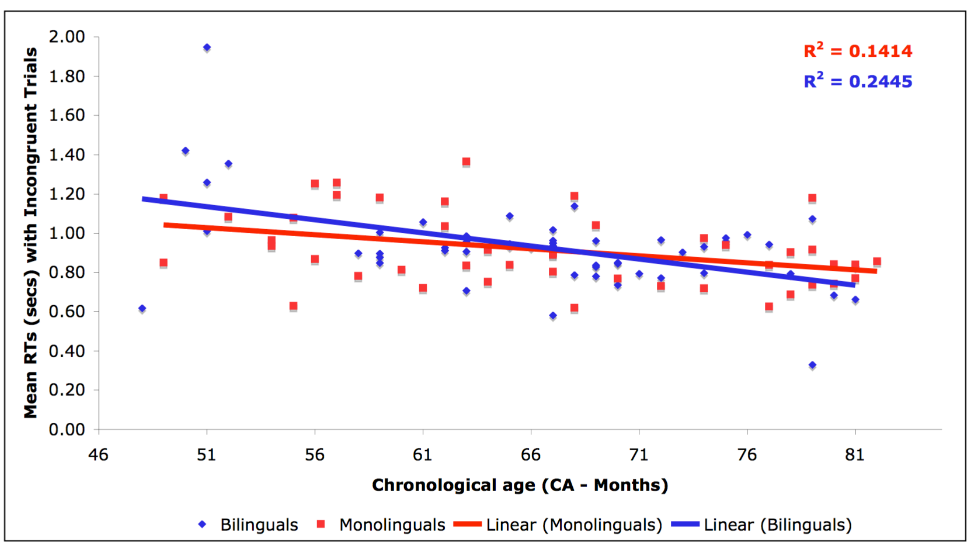


Figure 5.3: Developmental trajectory in performing the Simon Task with incongruent trials: Comparison of bilingual and monolingual children reaction times.

Mixed-design ANCOVA for reaction times revealed that the trajectory accounts for 21% of the total variance, $F(3,95)=8.250$, $p<.001$, $\eta^2=.207$). There was no significant main effect of language group, $F(1,95)=2.188$, $p=.142$, $\eta^2=.023$, indicating that the intercepts of the two groups were similar. Thus, bilinguals and monolinguals' performance started approximately at the same level. With the groups combined, there was a significant main effect of age, $F(1,95)=23.142$, $p<.001$, $\eta^2=.199$, revealing that bilinguals and monolinguals became faster in the responses with increasing age. In this case, reaction time with incongruent trials decreased as children grew older. A non-significant interaction between group and age, $F(1,95)=1.119$, $p=.149$, $\eta^2=.022$, indicated that bilinguals and monolinguals' did not significantly differ in performing the Simon task with the most demanding condition, the incongruent trials. Similar results were found for the congruent condition. Moreover, a parallel comparison splitting groups into quartiles age ranges did not reveal reliable group differences in any quartile. In sum, the same group of children in whom bilinguals showed a vocabulary disadvantage and differential developmental trajectory, showed no effects of bilingual status on an executive function task and an identical developmental trajectory. To rule out the possibility that this non-significant result could be attributable to a small number of participants I carried out a power analysis using G*Power (Erdfelder, Faul, & Buchner, 1996). Power analysis indicated that the power to detect obtained effects at the 0.05 level was 0.84 for the overall regression in prediction of differences in the Simon task between bilingual and monolingual children. Thus, there was an 84% chance to detect a genuine effect, it seemed highly unlikely that the negative results were due to sample size.

Parental Socio-economic status (SES), vocabulary knowledge and executive function

The relationship between the BPVS scores, the Simon Task, and parental SES was investigated via multiple regression analysis. The analysis was compromised by the fact that not all parents returned the questionnaire and, in some cases, the information was not provided in questionnaires that were returned. Therefore, only 67 children out of 99 were included in the analysis; thirty-six of them were from bilingual families. Additionally, the measure of SES did not include family income at the school's request. Thus, it was related only to a partial dimension of socio-economic status, that is, parental levels of education. As already reported in Chapter 3, averaged parental educational level scores (i.e., 1=Primary/Elementary school, 2=High school, 3=University or higher), indicated that bilingual and monolingual parents had a comparable education, mean=2.61 (SD=0.46) for bilingual parents, and mean=2.65 (SD=0.49) for monolinguals, and equally distributed educational levels, $\chi^2(2)=1.33$, n.s. Twelve bilingual families out of 36 (33%) had one English native speaker parent and were scored 1 point. The remaining bilingual families in which both parents were not native speakers of English were scored 0 points.

A correlation analysis was carried out including all children, regardless of their language status. Parental educational levels (SES) were correlated with the children's ability scores in the BPVS and their performance in the Simon Task in terms of reaction times for congruent and incongruent trials. Moreover, following Morton and Harper (2007), the difference between incongruent and congruent trials was computed (Simon cost) and added to the analysis. Pearson's correlation coefficients and p-values are reported in Table 5.3.

Table 5.3: Relation of parental SES and the children's performance in the BPVS and the Simon Task. The only significant correlation between SES and the BPVS is highlighted in grey.

Correlation	Pearson's Corr. Coeff.	p-value
SES and BPVS	**.449**	**.001**
SES and Simon Task (Congruent trials)	-.012	.33
SES and Simon Task (Incongruent trials)	-.007	.58
SES and Simon cost (Incongruent - Congruent trials)	.009	.49

The reliable positive correlations were between SES and the BPVS. There was no reliable correlation between SES and all the other measures of the Simon task. These results are in line with previous findings showing a crucial role of the family in the emergence of language and word learning (e.g., Hart and Risely, 1995).

A multiple regression analysis was carried out on the 36 bilingual children whose questionnaire was filled and returned by their parents. The two independent variables used in this model were: (1) the SES scores of parental education; (2) the SES scores when at least one parent was a native speaker of English. The dependent variable was the children's test age equivalent in the BPVS.

Table 5.4 presents the results of the model. As reported in the previous correlation analysis including all children regardless of their language status, the parental SES for education level was a significant predictor for vocabulary acquisition (p=.021) for bilinguals. However, having at least one parent native speaker of English in bilingual families was an even more significant predictor (p=.005). Parental SES scores combined explained 36.4% of the variance.

Table 5.4: Multiple regression analysis. Parental SES and L1 regularly spoken in the family predicted best performance in the BPVS.

	B	SE B	β	R^2 Change
Constant	29.042	12.963		
Parent L1 speaker	14.521	4.845	.426**	.250
Parental level of education	6.049	2.493	.345*	.114

R^2=.364; **p=.005; *p=.021.

5.4 Discussion

The main aim of this study was to establish whether early multi-language bilingual children had a vocabulary disadvantage and an executive function advantage when compared with age-matched monolinguals. Their performance in a standardised test for English receptive vocabulary, the BPVS (Dunn, Whetton & Pintilie, 1997) and in an executive function task, the Simon Task (Lu & Proctor, 1995; Simon & Wolf, 1963), was analysed in a cross-sectional study with children ranging from 4 to 7 years old and having equivalent intellectual ability.

In line with previous findings comparing the mean standard scores (e.g., Bialystok & Feng, in press), English monolingual children generally outperformed their bilingual peers in their receptive vocabulary. However, a developmental trajectory revealed that bilinguals did not show an overall delay in English language acquisition over development when compared with monolinguals. Bialystok and Feng (in press) found a significant bilingual delay in English acquisition throughout development, from 5 to 9-year-old (Cohen's *d*=0.8). In contrast, we found an uneven pattern of second language acquisition: 4-year-old and 6-year-old bilinguals showed this delay, but children of about 5 years of age did not. If this effect was real, an immediate answer cannot be provided in this study. A possible explanation is that this pattern could result from chance differences in sampling. Alternatively, this difference could be explained in terms of different parental SES. Unfortunately not all parents returned the questionnaires to allow us to carry out a more thorough analysis. However, for the known data, a combination between parental level of education and the regular use of English at home with at least one parent native speaker of English, robustly predicted a better L2 vocabulary acquisition. With both groups combined, parental level of education confirmed a significant predictor for best performance in language acquisition, supporting previous research that highlighted the fundamental role of the family (e.g., Hart & Risely, 1995).

This study failed to replicate previous findings showing a bilingual advantage in executive function over monolinguals. Ricciardelli (1992) found a cognitive control advantage only in balanced bilingual children, namely, children with high levels of proficiency in both languages. The author argued that these findings were in line with the *Threshold Theory* (Cummins, 1976), which postulates that if proficiency is only in one language, bilingualism will have neither positive nor negative effects on cognitive development. Given the variety of languages spoken by the bilingual children in this study, it was not possible to test this hypothesis. However, according to Bialystok (1988a), bilinguals, irrespectively of their degree of proficiency, may be more advantaged in executive function (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004). Despite the fact that the Simon Task proved to be sensitive in the way it showed improvement over age, the two group's performance in this study was comparable across this range. Finally, in contrast with Morton and Harper (2007), there was no evidence that SES predicted executive control performance in the Simon Task with both groups.

The results of this study highlighted the importance of assessing bilingual children's skills before conducting a research study. Individual differences in terms of the children's ethnic background, use of first and second language, similarity of their first language to English, socio-economic status of their families and school teaching environment, may bring into question the robustness of previous executive function and vocabulary results. It is therefore essential to rule out any possible confound that might have an effect on bilingual research. The bilingual children who took part in this study were exposed to English either since birth or before the age of three, used both languages regularly, attended the same school, lived approximately in the same area and had parents of comparable educational level. They showed an overall typical development in English acquisition when compared with monolingual peers, although the trend was not linear. All children had similar intellectual and executive function abilities regardless of their language status. Although the heterogeneity of procedures and samples in large-scale studies helped researchers finding a general effect, they cannot provide an accurate dimension of bilingual language development. The use of developmental trajectories showed that the measures were sufficiently sensitive to detect developmental changes in verbal and non-verbal skills.

5.5 Conclusions

In summary, this study provided evidence that a developmental approach to bilingual research could shed new light on bilingual children's linguistic and non-linguistic development. In an increasingly multi-ethnic society, it is important to provide further scientific evidence that could prove useful to the development of educational and culture integration programmes, and to mitigate the parental concern that bilingualism could somewhat impair the normal development of a child.

In the next chapter, I will investigate possible differences between bilingual and monolingual children using a probabilistic learning paradigm.

Chapter 6

Study 2: Probabilistic Learning in early bilingual children

6.1 Introduction

A crucial task for young children's cognitive development is to extract patterns and regularities from their environment. For example, in language acquisition children must learn both words and grammatical rules. This process may seem particularly challenging for bilingual children who must face two different vocabularies and syntactic systems coming from different input sources. Thus, the fundamental questions in bilingual research is how the developing cognitive system deals with utterances and regularities belonging to two different languages and what impact, if any, accommodating this complex linguistic input may have on the development of other cognitive abilities.

In our previous study, bilingual and monolingual children did not perform differently in an executive function task, the Simon task. However, as we have seen in Chapter 2, researchers have reported evidence showing that mastering two languages from an early age may influence certain non-verbal domains of cognitive functioning (e.g., Bialystok, 1999; Bialystok et al., 2005; Bialystok & Martin, 2004). These possible advantages were shown in paradigms where bilinguals were explicitly told the rules to follow (e.g., card sort, grammatical judgment, and Simon tasks). Less attention has been given to whether bilinguals still show this advantage when the underlying rule of a task is not explained beforehand.

Perhaps the first attempt in this direction was the recent work of Kovács and Mehler (2009), who investigated a possible bilingual advantage in pre-verbal bilingual infants. Their assumption was that not only speaking two languages but also having to carefully monitor the linguistic signal to distinguish each of the two languages would enhance certain cognitive functions before infants actually start to speak. Kovács and Mehler (2009) administered a series of eye-tracking experiments to 7-month old bilingual and monolingual infants matched by age, gender and parents' socio-economic status. Infants were presented with two symbolic rules simultaneously followed and matched with conflicting feedback. The overall results showed that while monolingual infants learned only one rule when simultaneously confronted with two structural rules, bilinguals of the same age succeeded in learning both rules (Cohen's d=0.8). The authors claimed that that early experience with multiple language systems leads to a greater cognitive flexibility, and that this advantage is already evident at a pre-verbal age.

To test the hypothesis that implicit rule learning may also be advantaged in school-age children, I used a probabilistic learning paradigm with a binary forced-choice response and conflicting feedback (Muenke, Shohami & Kirkham, 2009) with the same children who took part in Study 1. Children saw pictures of two different Mr. Potatohead dolls on a computer screen, one wearing a hat, one wearing glasses. Their task was to guess each character's favourite colour balloon (Green or Yellow). After each guess, they were given feedback (i.e., the colour balloon this Mr. Potatohead liked). The balloon outcome was determined by the association between the colour and the feature (e.g., doll wearing a hat preferred a green balloon 80% of the time and a yellow balloon 20% of the time). Thus, the underlying rule was based on the 80-20 probabilities for each Mr. Potatohead. Children were not told these rules beforehand, but their responses were monitored to see whether they could pick up on the rules, and whether their strategy changed following the 20% of trials in which the rule was violated.

This was an exploratory study addressing two main questions:

1) Will bilingual children show better learning than monolinguals for the underlying regularity?

2) How will positive (80%) and negative (20%) feedback affect behaviour in the two groups?

No specific prediction was made, although previous findings suggest that bilinguals may generally show better cognitive flexibility than their monolingual peers. This could result in better implicit learning of the underlying rule throughout development. However, it may manifest in the children's behaviour after the presentation of a negative feedback trial. If bilinguals are better at inhibiting previously learned rules than monolinguals, the repetitive and random administration of negative feedback might have a detrimental effect to their learning strategy and, if so, their performance might be worse than monolinguals.

6.2 Methods

Participants

The same bilingual and monolingual children who took part in Study 1 also participated in this study.

Tasks and Procedure

The same general procedure described in Chapter 3 was used.

Probabilistic Learning Task

Children were presented static pictures of two distinct Mr. Potatoheads on a black background. The two Mr. Potatoheads shared some fixed features such as pink ears, red nose, blue shoes, arms, hands and eyes, and individual distinct features: one wearing a blue hat and the other wearing green glasses. All stimuli were presented on a 15” MacBook laptop. A two-button keypad was connected to the laptop to record the children’s responses. Two stickers representing a green (left-button) and a yellow balloon (right-button) were applied on the buttons. The equipment used for this task is displayed in Figure 6.1.

Figure 6.1: The equipment used in the probabilistic learning task: a MacBook laptop and a child-friendly two-button keypad.

Children were instructed to guess which one of the coloured balloons the Mr. Potatohead appearing on the screen liked, and press the button accordingly. Each Mr. Potatohead was probabilistically associated with either a green or a yellow balloon. For example, the Mr. Potatohead wearing a hat liked the green balloon 80% of the time, and preferred the yellow balloon 20% of the time. Conversely, the Mr. Potatohead character wearing glasses, liked a yellow balloon 80% of the time and a green balloon 20% of the time. On each trial, children were shown a Mr. Potatohead without a balloon, and were asked to press the button according to what colour balloon they thought Mr. Potatohead preferred (target trial). Following the child’s response, the children were presented a new slide with feedback, that is, the Mr. Potatohead holding either a green or a yellow balloon.

The feedback slide was shown for 3 seconds after the child's response. If a response was not given within 10 seconds, the feedback showed automatically for three seconds before moving on the next trial. Fifty trials were presented in sequence.

There were 4 pseudo-randomised orders for this task, counterbalanced by each participant. The less likely balloon preferences (i.e., those with 20% probability occurring), were defined as *negative feedback trials* and pseudo randomised across each order according to the following rule: 1) Five negative feedback trials in each block of 25 trials; 2) No more than two consecutive negative feedback trials; and, 3) negative feedback trials appearing in different positions across the four orders.

Additionally, I defined *negative feedback cases* those trials that presented the Mr. Potatohead doll immediately after a negative feedback trial displaying a doll with identical characteristics. For example, the doll wearing the hat (e.g., most likely associated with the green balloon) was followed by negative feedback (i.e., it was associated with the yellow balloon). The following trial presented the same doll wearing the hat. Thus, a negative feedback case occurred when the children had to decide if sticking with the most likely association (i.e., the green balloon), or changing to the new rule in accord with the latest presented trial (i.e., the negative feedback case). There were 5 negative feedback cases in each order.

A schematic illustration of the task is displayed in Figure 6.2.

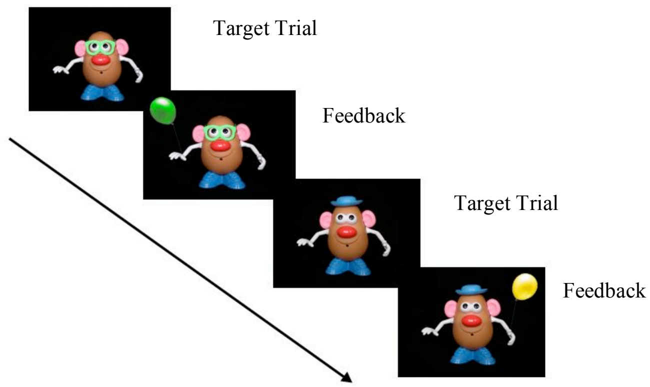


Figure 6.2: An illustration of the probabilistic learning task.

Two versions of the test were created. In version one, the following implicit rules were included, operating with 80% validity: glasses feature → green balloon; hat feature → yellow balloon. In version two, the following implicit rules were included, operating with 80% validity: glasses feature → yellow balloon; hat feature → green balloon. Children were assigned one of the two versions at random.

Instructions and interaction during the task between the child and the experimenter were in English. Once the task was completed, children were administered a drawing task in which they were given a green and a yellow crayon and a paper showing the two Mr. Potatoheads with a blank balloon. Children were then asked to colour in with the colour they thought Mr Potatohead liked. This transfer task was used as a measure of explicit learning, following Muenke, Shohami and Kirkham (2009).

6.3 Results

The primary dependent variable in this study was the accuracy of correct responses throughout the 50 trials of the task. Correct answers were defined when the child guessed the colour balloon that was most often associated with the Mr. Potatohead, that is, 80% of the time. Data analysis was split into two parts of 25 trials each. The first part was considered as a 'learning phase' and the second part as a 'consolidation phase'. Children received an equal number of negative feedback trials in both parts. Data were analysed with a mixed-design ANCOVA for task part at two levels (learning phase, consolidation phase) as the within subject factor. The between-subject independent factor was *language group* at two levels (bilinguals, monolinguals). The covariate factor was *age,* ranging from 48 to 82 months. There was no significant main effect of group, $F(1,96)=1.841$, $p=.178$, $\eta^2=.019$, no significant main effect of age, $F(1,96)=1.186$, $p=.279$, $\eta^2=.012$, and no main effect of task part, $F(1,96)=.064$, $p=.801$, $\eta^2=.011$. The interaction between task part and group was also non-significant, $F(1,96)=1.814$, $p=.181$, $\eta^2=.019$. These results indicated that the bilingual and monolingual children had comparable performance in both learning and consolidation phase, and age did not predict any improvement in the probabilistic learning task. To check if implicit learning had occurred, a 1-way ANOVA comparing bilinguals vs. monolinguals and two paired-samples t-tests comparing monolinguals' and bilinguals' performance with chance level, were carried out separately for the learning phase and for the consolidation phase.

For the learning phase, one-way ANOVA revealed a significant difference between bilinguals and monolinguals, $F(1,98)=4.649$, $p=.034$ (Cohen's $d=0.43$). The t-tests confirmed that both bilingual and monolingual children's performance was better than chance level, which is represented by the dashed line in Figure 6.5, t(53)=2.674, p=.010; t(44)=5.311, p<.001, respectively.

For the consolidation phase, one-way ANOVA revealed a non significant difference between bilinguals and monolinguals, F(1,98)=.115, p=.735, *n.s.* The t-tests confirmed that both bilingual and monolingual children's performance was better than chance level, which is represented by the dashed line in Figure 6.3 t(53)=3.704, p=.001; t(44)=4.624, p<.001, respectively.

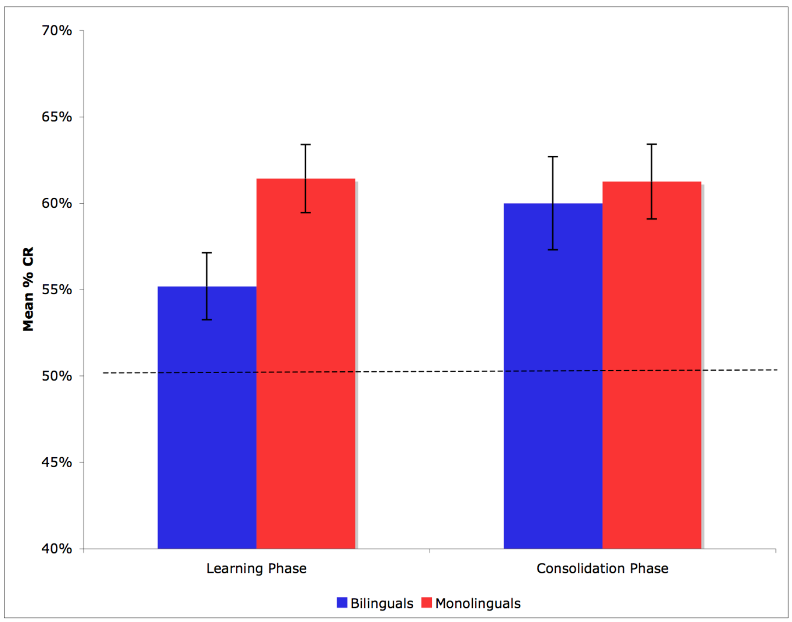


Figure 6.3: Bilingual and monolingual children's performance in the first and the second part of the probabilistic learning task.

In summary, overall results showed that learning occurred in both groups. However, monolinguals outperformed bilinguals in the learning phase. Bilinguals' performance was no different from monolinguals in the consolidation phase. The groups' performance did not improve with age. To check whether the non-significant results were due to a lack of statistical power, I conducted post hoc power analysis using

G*Power (Erdfelder et al., 1996). This indicated that the power to detect obtained effects at the 0.05 level was 0.76 for the overall regression in prediction of differences probabilistic learning between bilingual and monolingual children. A priori power analysis with power ($1 - \beta$) set at 0.80 and $\alpha = 05$, two-tailed showed that sample size would have to increase up to N = 128 in order for group differences to reach statistical significance at the 0.05 level. Thus, it is unlikely that the negative findings can be attributed to a limited sample size.

Did children understand the underlying rule?

The children's response in the drawing task was analysed to assess if explicit, transferable learning had occurred too. Correct performance in the drawing task was defined as colouring in the appropriate colour balloon associated with the two Mr. Potatoheads dictated by the relevant probabilistic rule. Children were given a 1-point score if the association was correct and a 0-point score if the association was incorrect. The scores were 32/54 for bilinguals and 29/45 for monolinguals. A chi-squared test indicated that these frequencies did not differ reliably from chance, indicating no evidence that explicit learning had taken place for either group, $\chi^2(1)=1.14$, *n.s.*

Did negative feedback affect bilinguals more than monolinguals?

A further analysis aimed to examine specifically the role of *negative feedback cases*, in which children were given a chance to either stick with the 80% balloon colour or switch to the 20% balloon colour.

Figure 6.4 displays the bilingual and monolingual children's percentage of correct responses after a negative feedback trial. Monolingual children outperformed bilinguals by 9% with a mean score of 61% correct responses against a bilingual mean score of 52% correct responses.

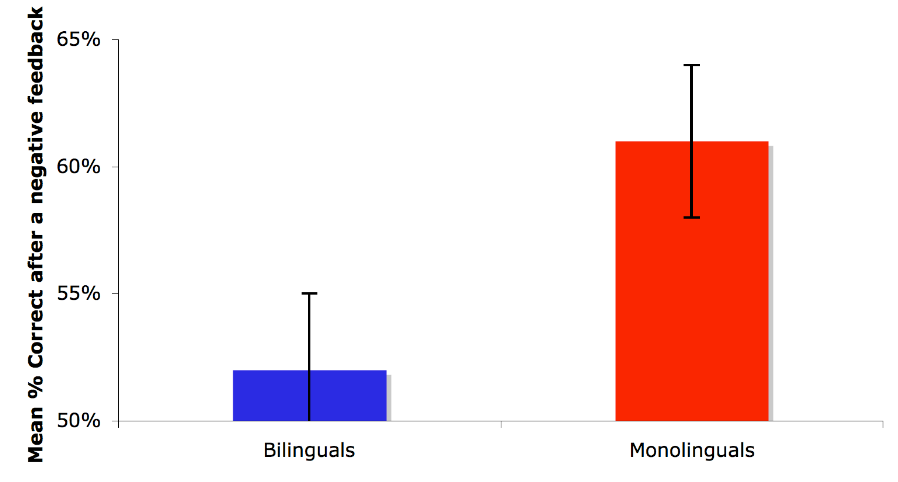


Figure 6.4: Children's percent of correct responses and standard errors when a trial was preceded by a negative feedback showing the same Mr. Potatohead character.

An independent one-way ANOVA for percent of correct responses after a negative feedback as the dependent variable and language group (bilinguals vs. monolinguals) as the independent variable, showed a marginally significant difference between the two groups, $F(1,97)=3.372$, $p=.069$, Cohen's $d=0.4$. This constitutes weak evidence that bilingual children were more sensitive than monolinguals to negative feedback for the probabilistic associations, and thus more inclined to change the rule. This marginally significant result remained unchanged when children's age was partialled out, suggesting that bilinguals were affected by negative feedback at all observed ages.

6.4 Discussion

The cognitive flexibility of bilingual and monolingual children from 4 to 7-year of age was explored in this study using a probabilistic learning paradigm with binary forced- choice responses and negative feedback.

Results showed that the groups had similar performance at all observed ages, although bilinguals reached the same level of accuracy of monolinguals only in the second part of the task (consolidation phase). There was a hint that monolingual children were more accurate than bilinguals when they had to respond after negative feedback. Their learning strategy seemed to be more robust, given our definition of what constituted success on the task. That is, when the monolinguals were given the choice to stick with the most likely probabilistic-associated rule or change to a new rule (definitely feedback violates the rule), they were less likely to switch rule. A possible explanation for this result could be that if bilinguals do indeed show greater cognitive flexibility in switching between rules (a flexibility which in this case would need to extend to implicit rules), then such flexibility would produce a disadvantage in a task where rules are only probabilistically defined.

The learning strategy in both groups did not improve over development as it might be expected. Similar results were obtained in the previous study in which bilinguals and monolinguals had comparable performance in an executive function task and in a general reasoning task. Power analyses conducted on both executive function and probabilistic learning tasks, showed that it is unlikely that these negative results can be attributed to a limited sample size.

Thus, given the same intellectual ability of all children at all observed ages, it is perhaps not surprising that their learning strategies were comparable.

6.5 Conclusions

The combined results from Study 1 and 2 did not provide convincing evidence for a general bilingual advantage in cognitive control or probabilistic learning. Both early bilingual and English monolingual children's performance was comparable across the age range. On the other hand, the probabilistic learning paradigm used in this exploratory study hinted at a possible disadvantage for bilinguals who may be poorer than monolinguals in learning probabilistic relationships if they have a propensity to switch between associations. This may cause them to lose track of the most likely probabilistic association and be disadvantaged given the task of extracting a rule in the face of noisy data.

Overall, despite its child-friendly design, this paradigm showed limited promise for explaining cognitive differences between bilingual and monolingual children due to its poor developmental sensitivity. The findings were suggestive, however, that flexibility may paralyze learning under condition of noise (invalid learning trials), and the avenue may be deserving of further explanation.

Chapter 7

Study 3: Attentional effects in language comprehension

7.1 Introduction

The ability to ignore distracting stimuli is highly relevant in everyday life. The effects of distraction on behaviour can have a range of detrimental consequences, (e.g., while carrying out a professional activity requiring high focus; during driving) and some that can simply reduce the quality of life (e.g., during reading; studying; watching a movie). One of the most compelling examples of this cognitive ability is attending to a conversation in the presence of distracting sounds, a phenomenon known as the *Cocktail Party Effect* (Cherry, 1953). Comprehending streams of speech in noisy environments, i.e., a room full of people talking simultaneously, requires cognitive mechanisms that allow us to select and concentrate on some aspects while neglecting others (see review in e.g., Driver, 2001).

Early research on selective attention predominantly used the dichotic listening paradigm, which involves the simultaneous presentation of two stimuli to the two ears via headphones. Participants are asked to attend one stimulus (target) and ignore the other (distractor). They are then asked to repeat aloud (shadowing method) just one of two stimuli. Results using this paradigm, that mimics the *Cocktail Party Effect,* revealed that participants had no or little memory for the information that they were told to ignore (Broadbent, 1952, 1954; Cherry, 1953). Occasionally, participants were able to detect some content of the unattended message, especially when there was a variation in physical acoustic properties, or different spatial and temporal characteristics (see review in e.g., Styles, 1997). Treisman (1964), also using the shadowing method, found that when the unattended message was in a foreign language, participants who knew that language were more prone to shift their attention to the wrong message. By contrast, participants were less distracted when the unattended message was in an unknown and phonetically different language (e.g., monolingual native English speakers listening to Czech).

However, the traditional shadowing method presented a fundamental problem: participants potentially knew little about the unattended message not because the information was not processed but because they could have forgotten it when asked the experimental question. More recently, experimental paradigms attempted to resolve this issue by measuring directly the effect of distractors on processing the target message. Research in the last three decades has focused on the role of perceptual characteristics affecting processing in the auditory system, investigating energetic and informational masking effects on speech comprehension in a multi-talker environment. Energetic masking is commonly defined as the competition between the target sound and the interference at the periphery of the auditory system. For instance, if two competing sounds have the same frequency, i.e., contain energy in the same band at the same time, one or both signals might be inaudible. Informational masking is, in contrast, a higher-level process, which occurs when both signals are audible but the listener is not able to disentangle the attended from the unattended message (Dirks & Bower, 1969; Festen & Plomp, 1990). Results from these lines of research (e.g., Bregman, 1994; Brokx & Nootebaum, 1982; Brungart, 2001; Brungart & Simpson, 2002; Darwin & Hukin, 1999) showed that a voice can be isolated in a multi-talker environment by focusing on its perceptual (i.e., vocal quality, pitch, and vocal tract length) or spatial characteristics (i.e., the difference in timing and intensity of the heard acoustic signal). It was also shown that comprehension improves as the number of talkers in the background increases (Hoen, Meunier, Grataloup, Pellegrino, et al., 2007).

In search of locus of attention: Early, late or both?

Research on selective attention has generated a long-standing (and not yet concluded) debate amongst those who hold that perception has limited capacity, so selection occurs immediately (*Early Selection view*, Broadbent, 1958), those who hold that all stimuli are processed until perception runs out of capacity (*Late Selection*, Deutsch & Deutsch, 1963)*,* and those who agreed that perception has a limited capacity, but non-selected stimuli are merely attenuated and can potentially reach awareness if relevant to the individual (*Early Attenuation view*, Treisman, 1960). More recently, this debate has been enriched by the work of Lavie (1995), who proposed that early or late selection is modulated by perceptual load. In her *Perceptual Load Theory*, Lavie proposed that distractor processing depends on the level (i.e., high vs. low) and the type of load (i.e., perceptual vs. working memory) involved in the processing of goal-relevant information. Lavie and colleagues used visual attention paradigms to demonstrate that when perceptual load is low, participants are more prone to distraction from non-attended stimuli. On the other hand, when the load is high, it will exhaust perceptual capacity and reduce if not eliminate the processing of task-irrelevant information. Interestingly, Lavie and colleagues found the opposite pattern when working memory was involved in the task. Their participants were required to memorise a sequence of digits in the presented order while performing a selective attention task in which they had to classify famous people, e.g., pictures of rock stars, in the presence of distractors, e.g., pictures of politicians (the *Successor-naming Task*). Results showed that when the sequence of digits to memorise was easy, e.g., 1-2-3-4-5, implying low working memory load, participants performed better in the selective attention task. By contrast, when the digits order was scrambled, e.g., 3-1-7-

4, implying a high working memory load, this caused greater interference in the selective attention task (de Fockert, Rees, Frith, & Lavie 2001).

The work of Lavie and colleagues showed that simply instructing people to focus attention on a certain task is not sufficient to prevent distractor interference. Rather, participants engage full attention when a high perceptual load is administered. In contrast, a high cognitive-control load increases distractor interference. The authors suggested that cognitive control is needed for actively maintaining the distinction between targets and distractors (Lavie, 2005).

Can the use of two languages enhance attentional processing?

As already discussed in the introductory chapters, the first half of the 20th century research on bilingualism almost uniquely highlighted the negative side of second language acquisition. However, research from the last four decades, although confirming some negative aspects (e.g., a bilingual deficit in lexical access, Bialystok, 2008), has suggested that the bilingual experience might provide a cognitive advantage in certain executive functions. This prompts the question of which aspects of the executive function particularly benefit from acquiring and using two languages. The primary processes in the executive system are inhibition, shifting of mental sets (task switching or cognitive flexibility), and updating information in working memory (Miyake et al., 2000). Bilinguals have been reported to outperform monolingual speakers in tasks requiring the inhibition of interfering irrelevant information (see Bialystok, 2009, for a review). This executive function ability has been shown both in a comparison of bilingual and monolingual children (e.g., Bialystok, 1999; Carlson & Melzoff, 2008) and bilingual and monolingual adults (Bialystok, Craik, Klein & Viswanathan, 2004; Costa, Hernández, & Sebastián-Gallés, 2008). One view relates the bilingual advantage in executive function to possible cognitive changes arising from managing two languages at the same time, a process that requires inhibition of the language not in use (Green, 1998). Thus, bilinguals may enhance cortical areas involved in executive functions through daily practice in switching between two languages.

Several visual paradigms have been used to measure and compare conflict resolution abilities between bilinguals and monolinguals, such as the card sort task (Bialystok, 1999; Bialystok & Martin, 2004), the attentional network task (ANT) (Costa et al., 2008), and the Stroop task (Bialystok, 2008). However, one of the most widely used tasks to study inhibition in monolingual and bilingual participants is the Simon Task (see a broader discussion in Chapter 2). Bialystok describes this task as the one which "*...incorporates the type of conflict that is more easily resolved by bilinguals and illustrates their advantage in executive processing*" (Bialystok, 2008, page 4). Bialystok and colleagues showed that bilinguals performed the task more easily than monolinguals by being faster in reaction times for both congruent and incongruent trials. This ability is maintained throughout the life-span as bilingual children (Martin-Rhee & Bialystok, 2008), young adults (Bialystok, 2006), and older bilingual adults (Bialystok, Craik, Klein & Viswanathan, 2004), outperformed their respective age-matched monolingual controls. The effect size of the advantage was quite large for children (Cohen's d =.90) and for older adults (Cohen's d =1.10), but less large for young adults (Cohen's d =.50). Based on the largest effect with the older adults, Bialystok and colleagues (2004) concluded that the life-long bilingual experience may attenuate the decline of executive functions as age increases. However, as we saw in the previous chapters, Morton and Harper (2007) questioned the robustness of Bialystok's work as they reported inconsistent data using the Simon Task with 6-7-year-old monolingual and bilingual children.

Overview for this study

The primary aim of this experiment was to determine if the bilingual executive function advantage at inhibiting irrelevant information found with visual tasks could also be generalised to auditory attention. For this purpose, a diotic listening design paradigm was used. In this task, the participant listened to auditory prerecorded sentences featuring two animals whose pictures appeared on a computer screen. The aim of the task was to identify the agent of the sentence while ignoring a competing sentence that was presented simultaneously in both ears. The sentences were produced by one male and one female speakers. Participants were prompted to attend sentences produced by just one speaker gender (target) and ignore the other (distractor). The task irrelevant sentences were either in the same or different language and the target language was the bilinguals' native or non-native language.

This paradigm has predominantly been used in cross-linguistic research to investigate how speakers of different languages use the various sources of information provided by a particular language (e.g., Bates, Devescovi & Wulfeck, 2001; MacWhinney & Bates, 1989). For example, sources of information are (1) the position of the agent in a sentence (i.e., the subject); (2) the agreement between the subject and verb in person and number; and (3) the contrast in animacy between the subject and the object of a given sentence. If a sentence like "*The dogs are biting the cat*" is considered, languages such as English rely more on word order (e.g. Subject-Verb-Object, S-V-O), whereas languages such as Italian rely more on noun-verb agreement (the conjugation of the infinitive Italian verb "to Bite", Mordere, is "*Mordono"* and can only be associated to the plural "*Dogs*"). This paradigm has also been used in clinical (Dick, Wulfeck, Aydelott, Dronkers, Gernsbacher & Bates,

2001) and developmental research (Dick, Wulfeck, Krupa-Kwiatkowski & Bates, 2004; Leech, Aydelott, Symons, Carnevale & Dick, 2007).

A battery of standardised and non-standardised tests was used to assess the participants' language dominance and levels of proficiency in English. Additionally, the Simon Task was also administered in this study.

Questions and Hypotheses:

1. Does language interference differentially affect attention and comprehension in bilinguals and monolinguals?
2. Does native and non-native language interference differentially affect attention and comprehension in bilinguals?
3. Does the bilingual experience enhance cognitive control by suppressing language interference and resulting in more efficient sentence comprehension?
4. Is selective attention modified by the difficulty of the syntactic construction as a measure of cognitive load?
5. If there is a cognitive advantage in suppressing speech interference, will this be replicated in a non-verbal task?
6. What is the role of proficiency for possible gains in selective attention?
7. If the answer to questions 4 and 5 is yes, do individual differences in selective attention in language task correlate with individual differences in the non-verbal task?

To answer these questions, I compared the linguistic and non-linguistic performance of a group of Italian/English bilingual adults with two groups of age-matched English and Italian monolinguals.

It was predicted that:

1. Bilinguals compared to monolinguals would show a cognitive advantage with an auditory task.
2. This advantage would be especially marked with higher cognitive load induced by processing the more difficult syntactic constructions.
3. Bilinguals would also show a cognitive advantage over monolinguals in a non-verbal executive function task, replicating previous findings using the Simon Task.
4. Proficiency would predict cognitive control gains in bilinguals, on the basis that bilinguals with more equal languages would have greater need of deploying inhibition for the task irrelevant language, and therefore greater skills in doing so.

7.2 Methods

Participants

Sixty healthy adults participated in this study in three groups: (1) 20 were Italian/English late bilinguals living in the UK (mean age 32.0, SD=6.3, range=20.2 - 40.7, 9 males) whose native language (L1) was Italian and whose second language, English (L2), was acquired on average after the age of 10.0 (SD=4.6); (2) 20 Italian monolinguals living in Italy (mean age 32.0, SD=10.0, range=19.4 - 49.7, 10 males); and (3) 20 English monolinguals living in the UK (mean age 30.1, SD=6.6, range=24.2 - 55.4, 8 males). Two Italian monolinguals could not complete all tasks and were excluded from data analysis. All participants signed an informed consent and did not report any visual, auditory or neurological impairment.

General procedure

All participants were tested twice in a quiet room by the same experimenter on the same equipment. They were administered a battery of six tasks that were counterbalanced across each experimental session. Bilinguals and English monolinguals were tested in the UK, Italian monolinguals in Italy.

Each session started with a short test to establish if the participants could successfully perform an auditory-motor task (Leech et al., 2007). This baseline measure consisted of 32 ‘ping’ sounds, each 0.3 seconds long, which were adapted from the alert sounds native to Mac OS 10.3. Participants pressed either the left or right button on a response keypad corresponding to the ear in which they heard a sound. Participants were asked to press the button as fast as they could with the thumbs of both hands. Bilinguals had a mean response time of 0.37 seconds (SD=0.06) and 99.5% accuracy (SD=11). The two monolingual groups together had a mean response time of 0.36 seconds (SD=0.08) and 98.5% accuracy (SD=2). A one-way ANOVA revealed no significant difference between bilinguals and the two monolingual groups for response time, $F(1, 57)=.204$, $p=.653$, ns, or for accuracy, $F(1,57)=3.200$, $p=.079$, ns. ANOVA also revealed no significant gender difference in performing the task.

Sentence Interpretation Task

Design

This experiment had a 5-factor, mixed design. The related measure independent variables were: (1) *sentence type* at four levels, active vs. passive, subject cleft vs. object cleft. *Sentence type* was later collapsed in two levels, canonical vs. non-canonical sentences; (2) *interference* at three levels, same language interference vs.

different language interference vs. no language interference; (3) *target language gender,* male vs. female; (4) *verb agreement* at two levels, cue and no-cue. For the purposes of this study the *verb agreement* factor was not analysed. The unrelated independent variable was *group* (bilinguals vs. English monolinguals vs. Italian monolinguals). For some analyses, the between subject factor was decomposed into two factors: (1) language (Italian vs. English), and: (2) *language group* (bilinguals vs. English monolinguals – bilinguals vs. Italian monolinguals).

The dependent variable was the accuracy in identifying the agent in each sentence. Reaction times were also collected and analysed to verify that there was no obvious evidence of speed-accuracy trade-offs. As target sentences and interference sentences were not time-locked, response time differences were not viewed as directly relatable to underlying interference. Therefore, in the following, only accuracy levels are reported.

Participants first performed the condition with language interference and subsequently carried out the second control condition without language interference. This was done at a different time, with a mean temporal gap of 53.3 days. Given they were adult participants, whose personal circumstances did not change radically between test sessions, it was assumed their language dominance would be relatively stable over a 2-month period.

Procedure

In the language interference condition, participants were told that they would see two drawings of animals presented simultaneously on a computer screen, one on their right and one on their left-hand side. They would also listen to a sentence featuring the two animals with one of them doing a “bad action” to the other. They were required to identify the animal doing the bad action. They were also told to ignore the other person talking simultaneously (always a different gender) and focus on the voice indicated on the computer screen at the beginning of the task. In the no-interference condition participants were just told to focus on the voice and identify the animal doing the bad action as no other stimuli was presented simultaneously. An illustration of the experimental setup is displayed in Fig. 7.1.

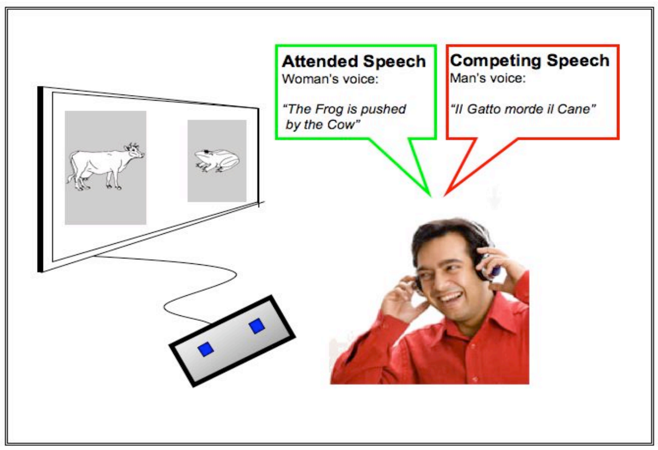


Figure 7.1: A schematic illustration of the task setup

Bilinguals were instructed in English. All participants completed 16 practice trial sentences for each experimental condition. The position of the subject animal (left or right) was counterbalanced across participants. Four random orders were created for both conditions, which were randomly allocated to the participants. Each trial was presented immediately following the subjects' response up to a maximum of 3 seconds, after which, if there was no response, the next trial was presented automatically. Trials were presented in short runs of variable size (4, 6, or 8 trials) in which the target language was alternated to maximise interference conditions and therefore the need for selective attention, i.e., a run in Italian was always followed by a run in English and vice-versa. Both language groups carried out the same task. Monolinguals were told to focus on and respond to the target sentences in their native language. When the target sentences were not in their native language, monolingual participants were asked to guess. In the language interference condition, the Italian and English sentences used as interference were counterbalanced in a way that participants could perform an equal number of congruent (i.e., ITA/ITA, ENG/ENG) and incongruent (i.e., ITA/ENG, ENG/ITA) trials.

Target and non-target sentences were created from a pool of animal nouns and action verbs using following criteria: (1) each animal appeared twice as subject, and twice as object; (2) each verb appeared twice; (3) no noun appeared with a verb more than once as subject, and no noun appeared with a verb more than once as object; (4) no two nouns were combined together twice; (5) the names of the animals were not cognates; (6) the verbs chosen were all high frequency verbs, transitive, and with mildly negative meaning; (7) attended and competing sentences were always spoken by different sex speakers and counterbalanced across languages; (8) attended and competing sentences were pseudo-randomised in a way that the same animals and syntactic structure would never be presented simultaneously in target and non-target sentences. Thus, the decision point for driving a response, would rarely if ever be simultaneous in target and non-target sentences; (9) competing speech was counterbalanced and equally presented in both native and non-native language; and (10) stimuli were presented binaurally.

All stimuli were adapted from the sentence interpretation task used previously in cross-linguistic (e.g., Bates, Devescovi & Wulfeck, 2001; MacWhinney & Bates, 1989) and language development studies (Dick et al., 2001, 2003, 2004; Leech et al., 2007). Stimuli were both visual and auditory. The visual stimuli represented drawings of familiar animals taken from several picture databases (Abbate & LaChappelle, 1984a, 1984b; Snodgrass & Vanderwart, 1980). Single pictures were 7.0 cm by 5.0 cm, digitised black-and-white line drawings, and displayed in pairs in accordance with the auditory stimuli (sentences featuring the animals). Each drawing was embedded in a solid grey rectangle surrounded by a white background. The auditory sentence stimuli consisted of 192 sentences in total, 96 English sentences and 96 translation equivalents in Italian, representing four syntactic structures: (1) active; (2) subject cleft; (3) object cleft; (4) passive. They were divided in two categories: (1) canonical Subject-Verb-Object (S-V-O); and (2) non-canonical Object-Verb-Subject or Object-Subject-Verb (O-V-S, O-S-V). Table 7.1 shows examples of these sentence types. Both Italian and English languages predominantly use a S-V-O word order (Bates, McNew, MacWhinney, Devescovi, & Smith, 1982). Thus, canonical sentences were taken to be easier and therefore presenting a low cognitive load (Roland, Dick, & Elman, 2006). Conversely, the non-canonical sentences were taken to be harder and more cognitively demanding (high-load processing).

Table 7.1: Example of sentence types (the agent is in bold)

Sentence Type	Constituent Order	English	Italian	No. of Sentences per Language
Canonical	Active (S-V-O)	The **frog** is pushing the seal	La **rana** spinge la foca	24
	Subject Cleft (S-V-O)	It's the **frog** that is pushing the seal	È la **rana** che spinge la foca	24
Non-Canonical	Passive (O-V-S)	It's the seal that is pushed by the **frog**	La foca è spinta dalla **rana**	24
	Object Cleft (O-S-V)	It's the seal that the **frog** is pushing	È la foca che la **rana** spinge	24

Equipment

Sentences were recorded by native speakers of British English or Italian, two females and two males, onto digital audio tape (DAT) in an Industrial Acoustics 403-A audiometric chamber with a TASCAM DA-P1 DAT recorder and a Sennheiser ME65/K6 supercardioid microphone and pre-amp at gain levels between 6 and 12 db. The recorded stimuli were then digitised via digital-to-digital sampling onto a Macintosh G4 computer via a Digidesign MBox using ProTools LE software at a sampling rate of 44.125 kHz with a 16-bit quantisation. The waveform of each sentence and animal name was then edited, converted into a 16-bit 44.125 kHz mono sound file in Audacity 1.2.5 for Mac, and saved in .wav format. Both target and competing speech signals were normalised to a root mean squared amplitude of 70 dB using Praat software (Boersma & Weenink, 2010), such that the average signal-to-noise ratio was zero (0) dB.

The experiment was presented on a MacBook 13' laptop computer using Matlab. The stimuli were presented through Sennheiser EH-150 headphones. Accuracy was recorded in Matlab from a USB Logitech Precision game-pad in which only two buttons were enabled, one on the right and one on the left.

Additional experimental measures

1. Simon Task

This task was already described in Chapter 5.

2. Lexical Decision Tasks

Bilinguals' and monolinguals' language competence was measured with two lexical decision tasks, one offline with low-frequency words to test word knowledge, and one online with high/medium-frequency words to test lexical access. Plausible non-words obeying the orthography and phonotactics were created for each language.

2a. Offline Lexical Decision Task

Fifty English words taken from Kucera and Francis (1967) database and 50 Italian words taken from the CoLFIS, corpus and frequency lexicon of written Italian (Laudanna, Thornton, Brown, Burani, & Marconi, 1995) were selected and presented on two separate scoring sheets. Words were matched as closely as possible on frequency within languages. Italian words had a mean frequency of 6.2 occurrences every three million (SD=5.0) and English words had a mean frequency of 10.0 per million (SD=6.4). Twenty five plausible non-words for each language were created by adding or subtracting vowels or consonants either at the beginning, middle or end of real words (e.g., Italian real word=*Confiscato*, non-word=*C**i**onfiscato;* English real word=*Colt,* non-word=*C**r**olt*). The word and non-word length was matched as closely as possible in each language (7.0 vs. 6.6 letters in Italian and 5.0 vs. 4.7 letters in English). Words and non-words were randomised and presented to all participants in the same order (Appendix 3). Participants were asked to tick "Yes" if the word was real or "No" if the word was a made-up word. There was no time limit for this task, but participants generally completed it in no more than 10 minutes. The number of correct responses both for words and non-words was scored. There were no practice trials for this task. Monolinguals performed the task in their native language, bilinguals performed it both in L1 and L2 versions.

2b. Online Lexical Decision Task

A list of 50 English words with a mean frequency of 46.7 (SD=14.1) occurrences per million were taken from the Kucera and Francis (1967) database and translated into Italian equivalents (e.g., *Mayor* = *Sindaco*). Fifty plausible non-words were created for both languages following the procedure described in the previous paragraph. All stimuli were randomised in two fixed orders, randomly allotted to participants, and presented on a computer screen. Subjects were instructed to press the left button on the USB keypad if they decided the word was real or the right button if not. They were also instructed to make their decision as quickly and accurately as possible. Bilingual participants were given 16 practice trials, 4 English words, 4 English non-words, 4 Italian words, and 4 Italian non-words. Monolinguals were given 8 practice trials, 4 words and 4 non-words, in their respective native languages. Each word was presented immediately following the subjects' response up to a max of 3 seconds, after which, if there was no response, the next word was presented automatically. Response time and accuracy were recorded and analysed. Monolinguals performed the task in their native language, bilinguals performed it both in L1 and L2 versions. The task took approximately 15 minutes to complete.

The list of words and non-words used in both lexical decision tasks is reported in Appendix II.

3. Bilingual Verbal Ability Tests

The Bilingual Verbal Ability Tests (BVAT - Muñoz-Sandoval, Cummins, Alvarado, & Ruef, 1998) is a standardised test to assess bilingual verbal ability. The BVAT contains three tests: 1) Picture Vocabulary, 2) Oral Vocabulary, and 3) Verbal Analogies (see Chapter 3 for more detail).

7.3 Results

Since language dominance will serve as a covariate in our analysis of performance on the bilingual diotic listening task, I begin by summarising the bilinguals' language competence levels. I then consider the main questions addressed in this study: (1) Does language interference differentially affect attention and comprehension in bilinguals and monolinguals? (2) Does native and non-native language interference differentially affect attention and comprehension in bilinguals? (3) Does the bilingual experience enhance cognitive control by suppressing language interference and resulting in more efficient sentence comprehension? (4) Is selective attention modified by the difficulty of the syntactic construction as a measure of cognitive load? (5) Will this cognitive advantage be replicated in a non-verbal task? (6) What is the role of proficiency for possible gains in selective attention?

In all sections, analyses of variance (ANOVAs) for Percent Correct Responses (accuracy) and Corrected Mean RT on accurate responses only (RT) are reported. ANOVAs were carried out with SPSS 16.0 for Mac.

English proficiency

Participants' raw scores, ranging from level 1 to 5 and increasing in units of 0.5 in order to have 9 degrees of proficiency, were computed using the *Scoring and Reporting Program for the BVAT*. The bilinguals' cognitive-academic language proficiency in English (CALP) is reported in Table 7.2 and graphically displayed in Figure 7.2.

Table 7.2: BVAT Cognitive-academic Language Proficiency: individual scores

Participant	*Sex*	*CALP*
1	F	4
2	M	3
3	M	4
4	F	5
5	F	2
6	F	5
7	M	3.5
8	M	3.5
9	F	3
10	M	3.5
11	M	5
12	M	3.5
13	F	3
14	M	1[2]
15	F	3
16	F	2
17	F	4
18	F	3.5
19	F	3.5
20	M	4

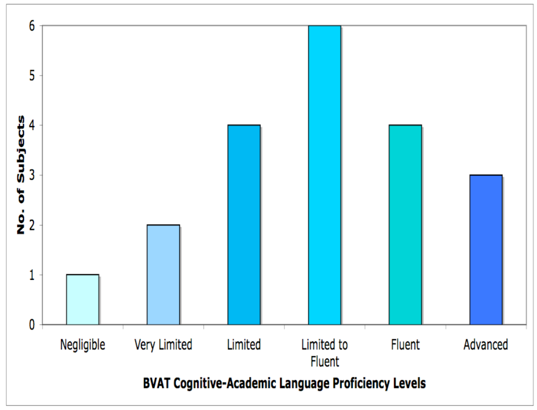


Figure 7.2: Bilinguals' English cognitive-academic proficiency distribution . Y-axis displays the number of participants and the X-axis their level of proficiency in English

Language competence: Lexical Decision Tasks

Italian and English monolinguals' mean accuracy and RTs in the lexical decision tasks compared with the bilinguals' performance in both languages are shown in Table 7.3.

[2] The Cognitive-Academic Language Proficiency (CALP) is a more refined index of proficiency provided by the Bilingual Verbal Ability Tests (BVAT), as described in Chapter 4. Note, a "Negligible" level of proficiency does not mean that the subject cannot speak English at a functional level.

Table 7.3: Participants reaction times (RT) in seconds and accuracy (% CR) in the Offline and Online Lexical Decision Tasks (LDT)

		Bilinguals		Italian Monolinguals		English Monolinguals	
		Mean	SD	Mean	SD	Mean	SD
Offline LDT English	CR Words	86.2	11.2	-	-	98.9	2.1
	CR Non-Words	81.4	14.2	-	-	92.4	6.3
Offline LDT Italian	CR Words	98.3	2.0	98.7	1.5	-	-
	CR Non-Words	89.4	13.5	91.1	10.8	-	-
Online LDT English	CR Words	95.6	2.8	-	-	95.1	3.3
	CR Non-Words	83.7	15.6	-	-	96.0	3.6
Online LDT English	RT Words	0.61	0.07	-	-	0.53	0.07
	RT Non-Words	0.86	0.18	-	-	0.61	0.12
Online LDT Italian	CR Words	98.7	2.1	98.4	1.6	-	-
	CR Non-Words	94.0	7.2	96.8	2.9	-	-
Online LDT Italian	RT Words	0.61	0.10	0.57	0.06	-	-
	RT Non-Words	0.83	0.16	0.74	0.09	-	-

For the offline lexical decision task the dependent variable (DV) was the mean percent of correct responses. Because there was a single group of bilinguals and two independent groups of monolinguals, this was analysed with two separate 2-way mixed ANOVA for stimulus type (low-frequency words, non-words) as a within subjects factor, and language group (bilinguals vs. Italian monolinguals and bilinguals vs. English monolinguals) as a between subjects factors.

As shown in Figures 7.3 and 7.4, for both groups in both analyses non-words were identified less accurately than words (bilinguals and Italian monolinguals, $F(1,36)= 16.100$, $p<.001$, $\eta^2=.309$; bilinguals and English monolinguals $F(1,38)= 15.175$, $p<.001$, $\eta^2=.285$).

For Italian, bilinguals were no less accurate than monolinguals ($F(1,36)= .275$, $p=.603$, $\eta^2=.008$). However, in English, the bilinguals were reliably less accurate, reflecting the fact that for them English was a late acquired L2 ($F(1,38)= 29.286$, $p<.001$, $\eta^2=.435$).

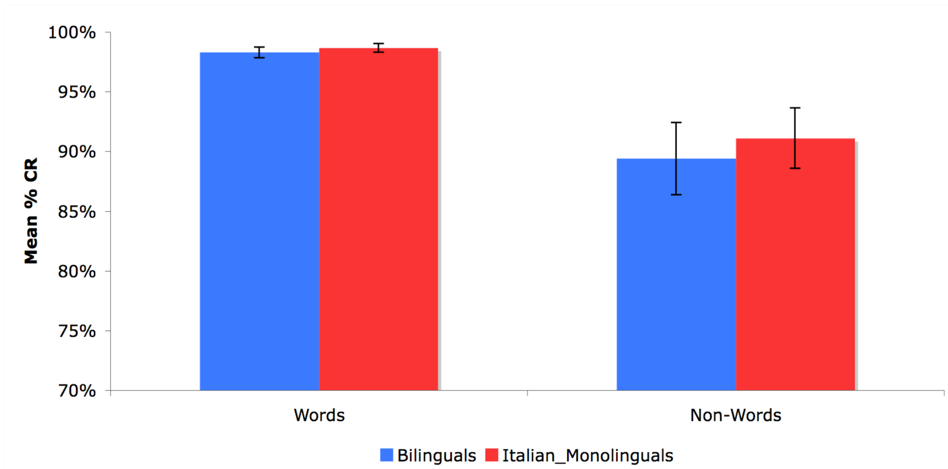


Figure 7.3: Mean percent of correct answers and standard errors for words and non-words in the offline lexical decision task: Bilinguals and Italian monolinguals comparison.

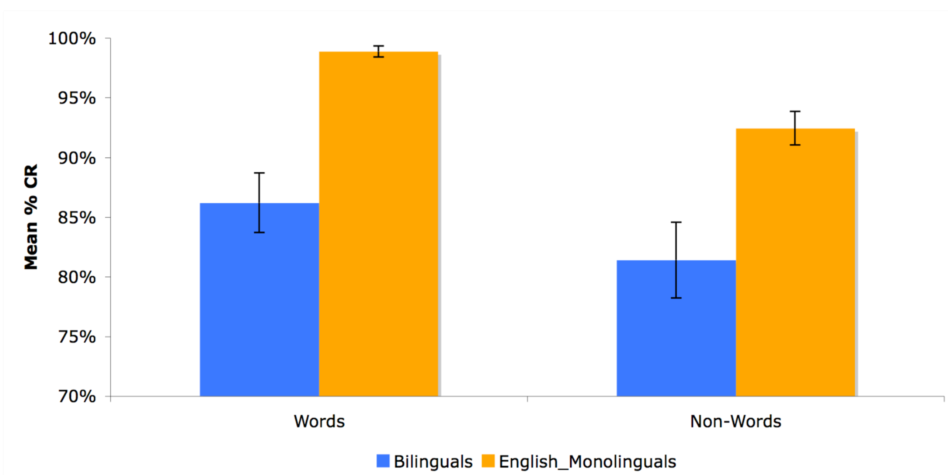


Figure 7.4: Mean percent of correct answers and standard errors for words and non-words in the offline lexical decision task: Bilinguals and English monolinguals comparison.

For the online lexical decision task the dependent variables (DVs) were RTs of valid trials and mean percent of correct responses. The DVs were analysed by separate 2-way mixed ANOVAs for stimulus type (medium-high frequency words, and non-words) as a within subjects variable, and language group (bilinguals vs. Italian monolinguals, and bilinguals vs. English monolinguals) as between subject variables. Analysis of reaction times showed a significant main effect of stimulus type for bilinguals and Italian monolinguals, $F(1,36)= 117.60$, $p<.001$, $\eta^2=.766$; and for bilinguals and English monolinguals $F(1,38)= 58.473$, $p<.001$, $\eta^2=.606$, indicating that all groups were slower in processing non-words than real words. For Italian, a marginally significant main effect of language group, $F(1,36)= 3.747$, $p=.061$, and interaction between stimulus type and language group, $F(1,36)= 3.178$, $p=.083$, indicated that bilinguals and Italian monolinguals' performance was broadly comparable, although bilinguals were reliably slower ($t=.039$) at processing Italian plausible non-words.

For English, analysis of variance revealed that English monolinguals were reliably faster than bilinguals at processing both stimulus type, $F(1,38)= 26.813$, $p<.001$, $\eta^2=.414$, especially with non-words group*stimulus type interaction: $F(1,38)= 16.074$, $p<.001$, $\eta^2=.297$. The interactions between the bilingual and monolingual groups' RTs are displayed in Figures 7.5 and 7.6.

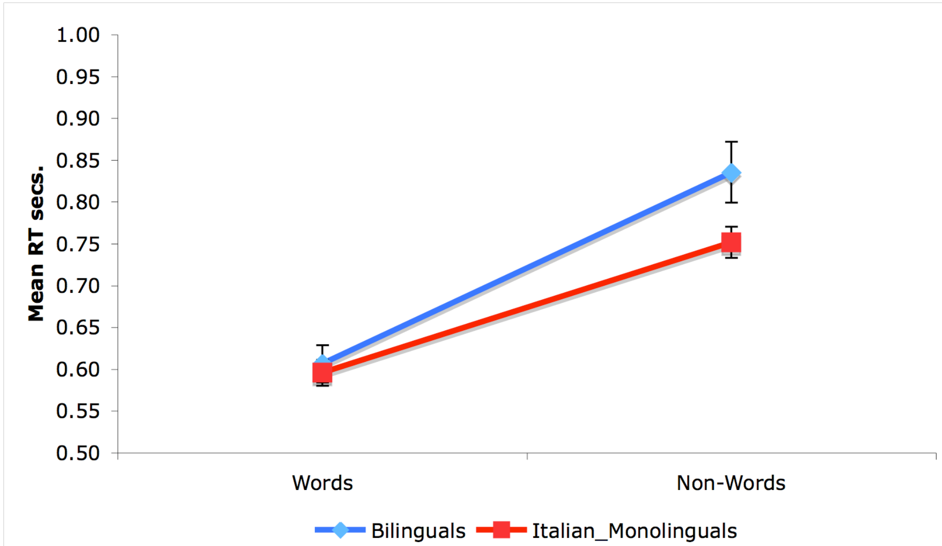


Figure 7.5: Mean RTs and standard errors for words and non-words in the online lexical decision task: Bilinguals and Italian monolinguals comparison.

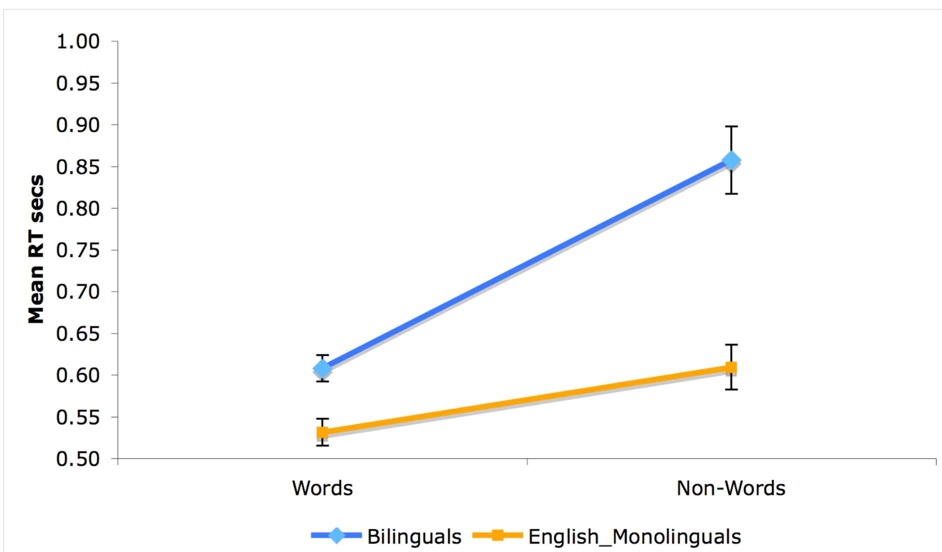


Figure 7.6: Mean RTs and standard errors for words and non-words in the online lexical decision task: Bilinguals and English monolinguals comparison.

Analysis of accuracy revealed that for Italian, bilinguals and monolinguals had comparable performance, $F(1,36)= 3.575$, $p=.067$, $\eta^2=.090$. However, as shown in Figure 7.7, a marginally significant interaction between group and stimulus type,

$F(1,36)= 3.505$, $p=.069$, $\eta^2=.089$, revealed that bilinguals were less accurate than Italian monolingual with non-words, although the difference was only marginally significant ($t=.055$).

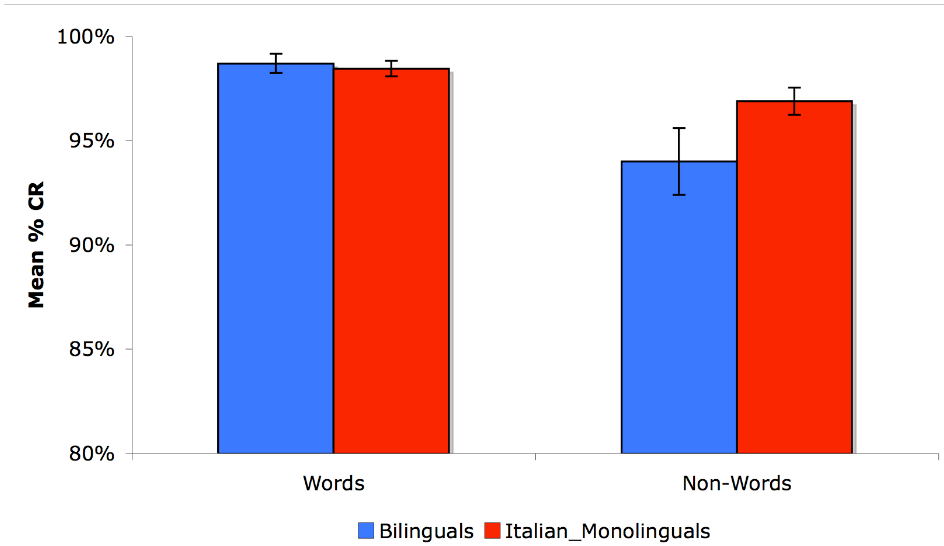


Figure 7.7: Mean percent of correct answers and standard errors for words and non-words in the online lexical decision task: Bilinguals and Italian monolinguals comparison.

For English, however, bilinguals and monolinguals showed a different pattern, $F(1,38)= 10.759$, $p=.002$, $\eta^2=.221$. Although both groups were generally less accurate with non-words, $F(1,38)= 8.142$, $p=.007$, $\eta^2=.176$, the interaction shown in Figure 7.8 indicates that the bilinguals made more errors with non-words than English monolinguals.

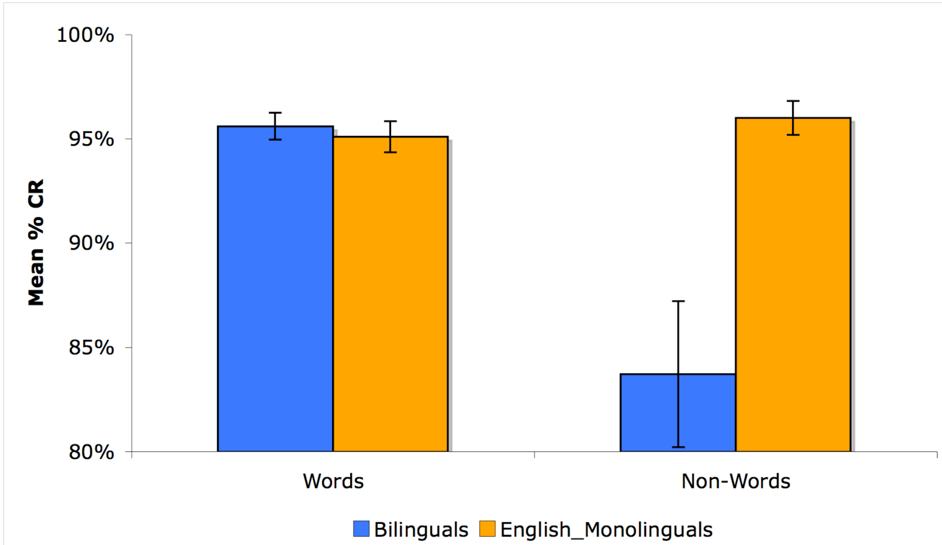


Figure 7.8: Mean percent of correct answers and standard errors for words and non-words in the online lexical decision task: Bilinguals and English monolinguals comparison.

Summary

The overall results for the online and the offline lexical decision tasks indicate that the bilingual participants showed a general better competence for words in their native language, that is Italian. Lexical decision for plausible non-words was particularly difficult in L2, (i.e., English).

In the next paragraphs, lexical access and linguistic competence were regressed against the bilinguals' levels of proficiency in English from the Bilingual Verbal Ability Tests (BVAT). The measures of language competence will later be used as covariates in other studies of this research project.

Correlation between English lexical access, linguistic knowledge, and L2 proficiency in bilinguals

Bilinguals' individual mean scores in the offline and online lexical decision tasks were correlated to the cognitive-academic level of proficiency in English obtained from the BVAT.

Proficiency and English lexical access

Analysis of data displayed in the scatter plot in Figure 7.9 using Pearson's *r* indicated that lexical access for English words was significantly negatively correlated with levels of proficiency, $r(20)= -.536$, $p=.015$. Thus, increases in proficiency are associated with decreases in reaction times for lexical access. Regression analysis revealed that level of proficiency in L2 makes a significant contribution ($p=.015$) to predicting faster lexical access in English. Cook's distance (Cook & Dennis, 1977) was inspected to determine whether a particular data point alone affected regression estimates. No data point was close to or greater than 1. This indicated that the model was not unduly influenced by outliers.

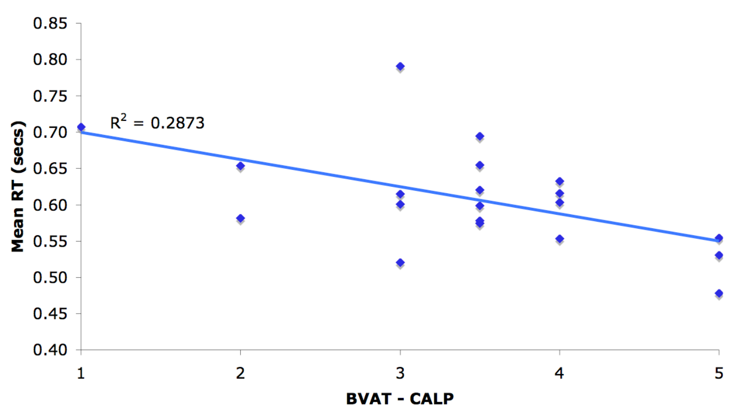


Figure 7.9: Correlation between reaction times in the online lexical decision task for English words and levels of proficiency from the Bilingual Verbal Ability Tests. Level 1 means low proficient and level 5 high proficient bilinguals.

Proficiency and English linguistic competence

Bilinguals' level of proficiency was significantly positively correlated with vocabulary knowledge in the offline lexical decision task both for words, *r* (20)=.462, p=.041, and non-words, *r*(20)=.556, p=.011. Figure 7.10 displays bilinguals' performance with non-words correlated with the cognitive academic level of proficiency assessed with the Bilingual Verbal Ability Tests.

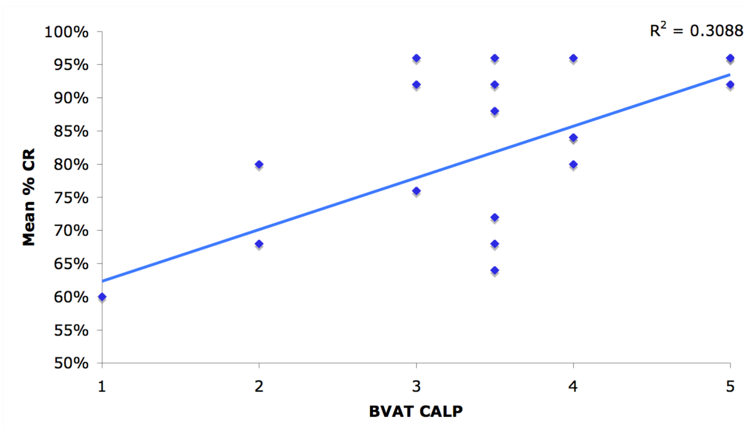


Figure 7.10: Correlation between accuracy in the offline lexical decision task for English non-words and levels of proficiency from the Bilingual Verbal Ability Tests. Level 1 means low proficient and level 5 high proficient bilinguals.

Sentence Interpretation Task

Accuracy in identifying the agent of each sentence was analysed by comparing the performance of bilinguals with English and Italian monolinguals in separate ANOVAs. When ANOVAs yielded significant interaction effects, pairwise comparisons (Bonferroni corrected) were carried out and an α level of .05 was used for all statistical tests. All groups showed that their level of accuracy for target sentences was not affected by the speakers' gender, and so analyses collapse over this factor.

Does language interference differentially affect attention and comprehension in bilinguals and monolinguals?

Bilinguals v. Italian monolinguals

In the control condition (without language interference) bilinguals had a 97.0% mean accuracy in the identification of the agent in the Italian sentences (SD=4.0). Italian monolinguals had similar performance (95.0% correct responses, SD=5.0). Bilinguals' level of accuracy decreased by 4.0% in the presence of English language interference (mean accuracy 93.0%, SD=8.0), and by 3% when interference was in Italian (mean accuracy 94.0%, SD=7.0). Italian monolinguals had a 6.0% drop when interference was in English (89.0%, SD=11.0), and a 10.0% drop when the language interference was in their native language (85.0%, SD=10.0). The two groups' performance with and without language interference is displayed in Figure 7.11.

Analysis of variance revealed a significant main effect of language interference, $F(2,72)=17.612$, $p<.001$, $\eta^2=.329$, a main effect of group $F(1,36)=4.934$, $p=.033$, $\eta^2=.121$, and significant interaction between interference and language group, $F(2,72)=3.685$ $p=.030$, $\eta^2=.093$, indicating that presence or absence of language interference had a differential effect on Italian sentence comprehension in the two groups. Bonferroni corrected *t*-test of sentence comprehension with native language interference showed that bilinguals were significantly less affected by L1 interference than their monolinguals peers, $t(36)=2.990$, p=.012. The results overall indicate that both groups were affected by language interference when compared with absence of interference, but more importantly, indicate that native language interference for monolinguals had a more detrimental effect than for the bilinguals.

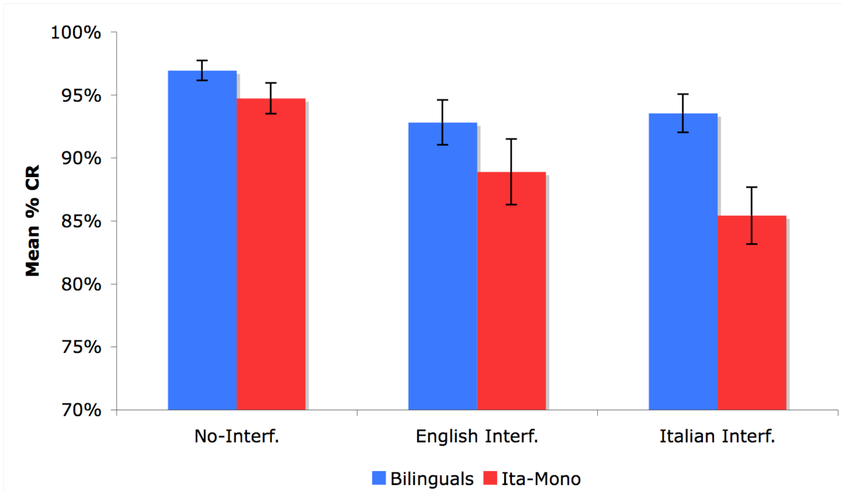


Figure 7.11: Bilinguals and Italian monolinguals percent correct responses and standard error bars in the presence or absence of non-native and native language interference

Bilinguals v. English monolinguals

In the control condition without language interference, bilinguals had a 95.0% mean accuracy in the identification of the agent in the English sentences (SD=5.0). English monolinguals showed a similar performance (96.0% correct responses, SD=5.0). The bilinguals' level of accuracy decreased by 5.0% in the presence of both English and Italian language interference (mean accuracy 90.0%, SD=9.0 in both cases). Compared to the control condition, English monolinguals had only a 2.0% decrease in their level of accuracy when interference was in a language they did not possess (94.0%, SD=8.0). However, their performance dropped by 8.0% when interference was in their native language, English (88.0%, SD=14.0). The two groups' performance with and without language interference is displayed in Figure 7.12.

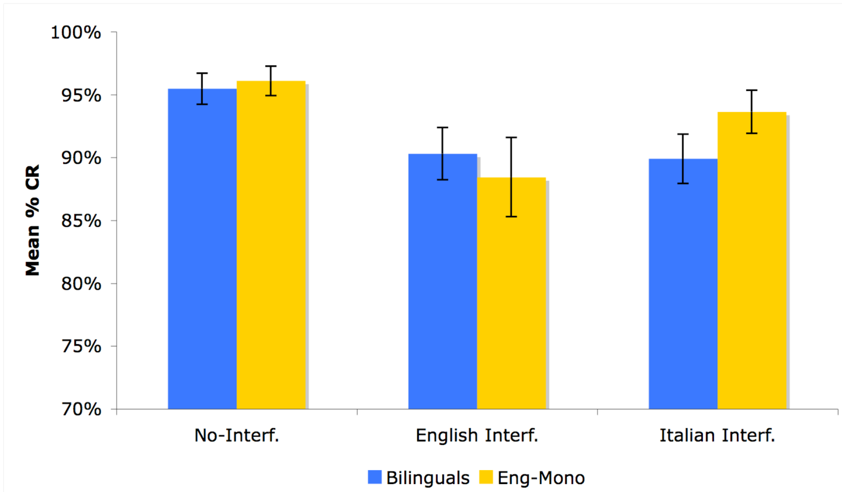


Figure 7.12: Bilinguals and English monolinguals percent correct responses and standard error bars in the presence or absence of non-native and native language interference.

ANOVA revealed a significant main effect of language interference, $F(2,76)=12.293$, $p<.001$, $\eta^2=.244$, but there was no significant main effect of group, $F(1,38)=.124$, $p=.727$, $\eta^2=.003$, and no significant interaction between interference and language group, $F(2,76)=2.326$, $p=.105$, $\eta^2=.058$. Individual t-tests comparing monolingual and bilingual performance for each interference condition were all non-significant. These results overall showed that both groups had comparable performance either in the presence or in the absence of language interference.

Were the two monolingual groups different?

The most salient result emerging from the previous sections indicates that bilinguals, whose dominant language was Italian, had similar performance when compared with

English monolinguals. However, they reliably outperformed their Italian monolingual peers. To rule out the possibility that the observed bilingual advantage was caused by an artifact of unmatched monolingual groups, a 3x2 mixed ANOVA for interference (no interference, native interference and non-native interference) as the within subjects variable and group (English monolinguals v. Italian monolinguals) as the between subjects factor was carried out. As shown in Figure 7.13, between subjects analysis revealed a non-significant main effect of group, $F(1,36)=1.547$, $p=.222$, $\eta^2=.041$. This indicated that the two monolingual groups performed equally in their respective languages. Language interference produced a significant decrease from baseline in both groups' performance, $F(2,72)=14.754$, $p<.001$, $\eta^2=.291$, but a non-significant interaction between group and interference, $F(2,72)=.588$, $p=.588$, $\eta^2=.016$, indicated that the performance of the two monolingual groups was affected in the same way: both English and Italian monolinguals were more affected by native language interference than non-native interference.

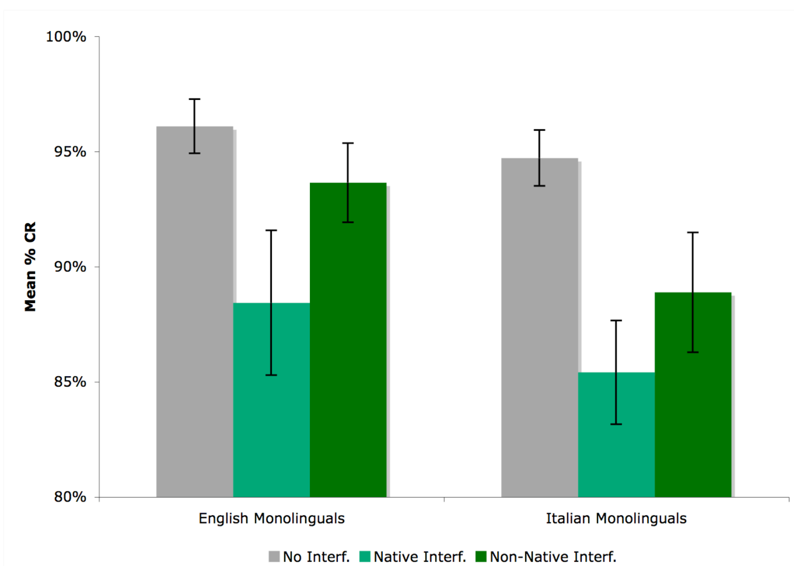


Figure 7.13: Monolingual comparison in the Sentence Interpretation Task: Italian and English participants' accuracy (CR) with and without language interference.

Did bilinguals perform differently in Italian and in English?

A 3x2 related ANOVA for interference (no interference, Italian interference and English interference) and target language (Italian, English) was also carried out to analyse the bilinguals' performance in Italian and in English. As shown in Figure 7.14 bilinguals predictably had a better performance when the target language was their native language, i.e., Italian, $F(1,19)=8.819$, $p=.008$, $\eta^2=.317$. There was a significant main effect of interference, $F(2,38)=14.108$, $p<.001$, $\eta^2=.426$, indicating that bilinguals, as monolinguals, were affected by the presence of a language distractor. However, a non-significant interaction between target language and interference, $F(2,38)=1.434$, $p=.251$, $\eta^2=.007$, revealed that the bilinguals' language difference was comparable regardless of the type of interference. In contrast to monolinguals, the pattern of interference in bilinguals was not modulated depending on whether it was caused by the native or non-native language.

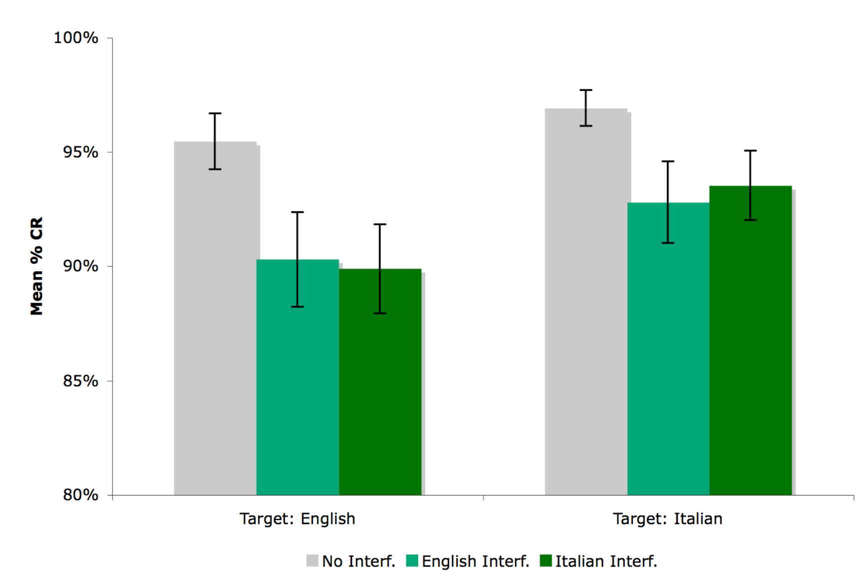


Figure 7.14: Bilinguals' performance comparison when performing the task in Italian and in English with and without language interference.

Summary

We saw an advantage in bilinguals in inhibiting interference from their dominant language compared to monolinguals of matched language ability. This advantage did not appear to be an artifact of unmatched monolingual groups. A cognitive advantage was not observed in the bilinguals' non-dominant language.

Will the bilingual advantage be especially salient in the presence of higher cognitive load?

Bilinguals v. Italian monolinguals

Cognitive load was defined by sentence type, specifically the contrast of processing easier canonical S-V-O sentences compared to harder non-canonical O-V-S sentences. Comparison of accuracy levels for bilinguals and Italian monolinguals indicated that both groups had similar performance when the cognitive demand was lower with canonical sentences.

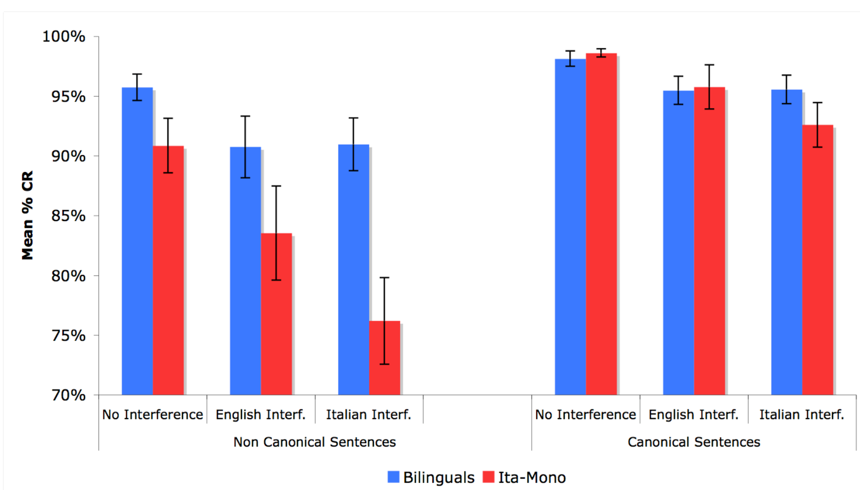


Figure 7.15: Bilinguals and Italian monolinguals' percent correct responses and error bars with non-canonical and canonical sentences in the presence or absence of non-native and native language interference.

A 3x2x2 mixed ANOVA for language interference (native, non-native, no-interference), sentence type (canonical, non-canonical), and language group (bilinguals vs. Italian monolinguals) revealed a significant main effect of sentence type, $F(1,36)=27.537$, $p<.001$, $\eta^2=.433$, a significant interaction between sentence type and group, $F(1,36)=7.226$, $p=.011$, $\eta^2=.167$, and a marginally significant third-order interaction for interference*sentence type*group, $F(2,72)=2.968$, $p=.058$, $\eta^2=.076$. Canonicity therefore had a clear effect on performance of the target sentence structure. Bonferroni corrected *t*-tests revealed no significant differences between groups for canonical sentences either in the presence or absence of language interference. However, for non-canonical sentences, bilinguals were significantly less affected by L1 interference than their monolinguals peers in the comprehension of non-canonical sentences, $t(36)=3.487$, $p=.003$.

These results indicated that when cognitive load is low, i.e., canonical sentences with native and non native-interference, both groups had comparable performance. Conversely, high cognitive demand affected both groups but had a particularly detrimental effect on Italian monolinguals, especially with native language interference. As we observed in the introduction, higher cognitive load is claimed to impoverish selective attention (Lavie, 1995), an effect to what the bilinguals appeared to be more resistant.

Bilinguals v. English monolinguals

The groups' percent of correct responses and standard errors are displayed in Figure 7.16.

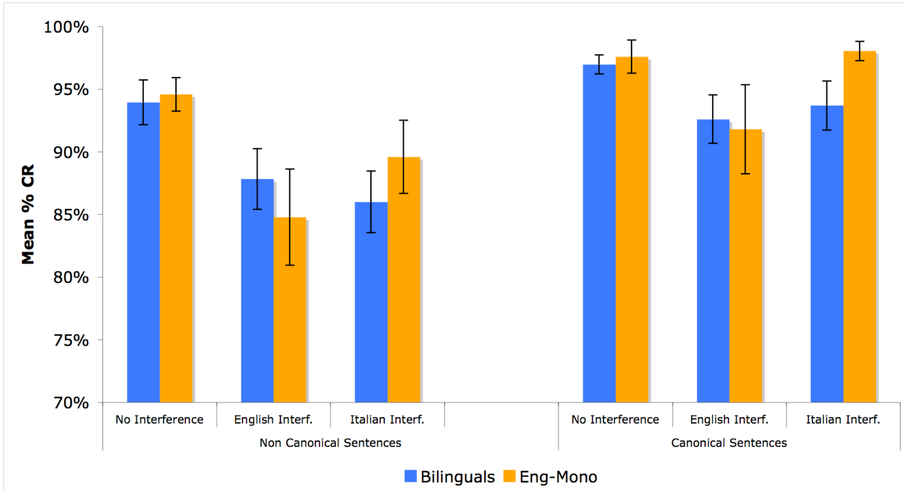


Figure 7.16: Bilinguals and English monolinguals' percent correct responses and error bars with non-canonical and canonical sentences in the presence or absence of non-native and native language interference.

A 3x2x2 mixed ANOVA for language interference (native, non-native, no-interference), sentence type (canonical, non-canonical), and language group (bilinguals vs. English monolinguals) revealed a significant main effect of sentence type, $F(1,38)=32.812$, $p<.001$, $\eta^2=.463$. There was no significant interaction between sentence type and group, $F(1,38)=.335$, $p=.566$, $\eta^2=.009$ and between interference*sentence type*group, $F(2,76)=.192$, $p=.826$, $\eta^2=.005$. The overall results indicated that both groups were more affected by higher cognitive demand, that is, they had a worse performance with non-canonical sentences comprehension in the presence of language interference. However, in contrast to the comparison with Italian monolinguals, canonicity affected the bilinguals and the English monolinguals in the same way.

Will word-order preferences in Italian and English drive differential effects for non-canonical sentences between English and Italian monolinguals?

A 2 x 3 mixed ANOVA for group (English monolinguals v. Italian monolinguals) as the between subjects factor and interference (no interference, native interference and non-native interference) as the within subjects variable was carried out. Figure 7.17 displays accuracy as a function of interference for the two monolingual groups with non-canonical sentences in the presence or absence of native and non-native language interference. This indicated that, although the English monolingual group's performance was somewhat higher in accuracy overall, there was no significant difference between the two monolingual groups, $F(1,36)=2.81$, $p=.103$, $\eta^2=.072$.. Language interference produced a significant decrease from baseline in both groups, $F(2,72)=19.57$, $p<.001$, $\eta^2=.352$. Critically, there was no significant interaction between group and interference, $F(2,72) <1$. The performance of the two monolingual groups was affected in the same way: English and Italian monolinguals were more affected by native language interference than by non-native interference when comprehending non-canonical sentences.

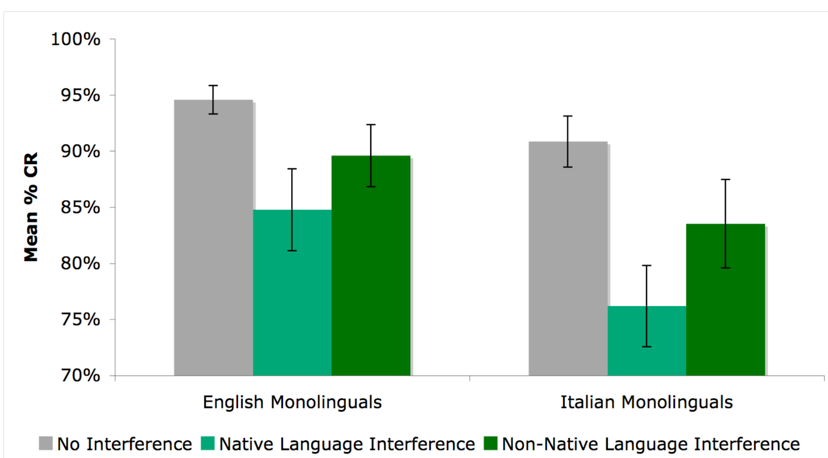


Figure 7.17: Monolingual comparison in the sentence interpretation task: Italian and English participants' accuracy (CR) with non-canonical sentences in the presence and absence of native and non-native language interference.

Summary

All groups had better performance when the cognitive load was lower, that is, with canonical sentences. A higher cognitive demand with non-canonical sentences, led to a decrease in accuracy in both bilinguals and monolinguals. However, bilinguals were better able at selecting attention to the target sentences in the presence of native interference than Italian monolinguals. When compared with English monolinguals bilinguals showed no difference despite the fact that they were non-native speakers of English and had levels of proficiency ranging from low to advanced. I now move to examine whether the attentional advantage observed for adult bilinguals in their L1 was also observed in a non-verbal task, the Simon task.

Will bilinguals show a cognitive advantage over monolinguals in the Simon Task?

English monolinguals vs. Italian monolinguals

Mean accuracy scores and reaction times for congruent and incongruent trials in the Simon task were first compared between the two monolingual groups. As shown in Figures 7.18 and 7.19, the English and Italian monolinguals' reaction times and degree of accuracy were similar: both groups were faster and more accurate with congruent than incongruent trials. A 2x2 mixed ANOVA for congruency (congruent v. incongruent trials) as the within subjects factor and language groups at two levels (English monolinguals and Italian monolinguals) as the between subject factor, indicated both groups were slower with incongruent trials, $F(1,36)=77.621$, $p<.001$,

η^2=.683. The main effect of congruency was marginally significant for accuracy, $F(1,36)=3.420$, $p=.073$, $\eta^2=.087$, indicating that the groups were less accurate with incongruent trials. A non-significant main effect of group showed that they the two groups were performing at a similar level, reaction times: $F(1,36)=1.312$, $p=.260$, $\eta^2=.035$; accuracy= $F(1,36)=.384$ $p=.539$, $\eta^2=.011$. A non-significant interaction between congruency and language group, reaction times: $F(1,36)=.017$, $p=.898$, $\eta^2=.001$; accuracy= $F(1,36)=1.097$ $p=.302$, $\eta^2=.030$, indicated that English and Italian monolinguals had comparable performance in the Simon task. This is further evidence of the equivalence of the monolingual groups.

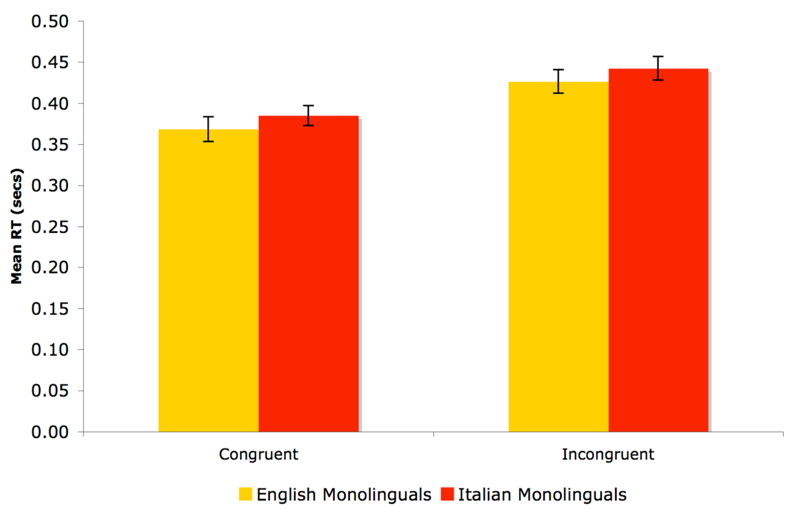


Figure 7.18: Reaction times for congruent and incongruent trials in the Simon task: comparison between English and Italian monolinguals.

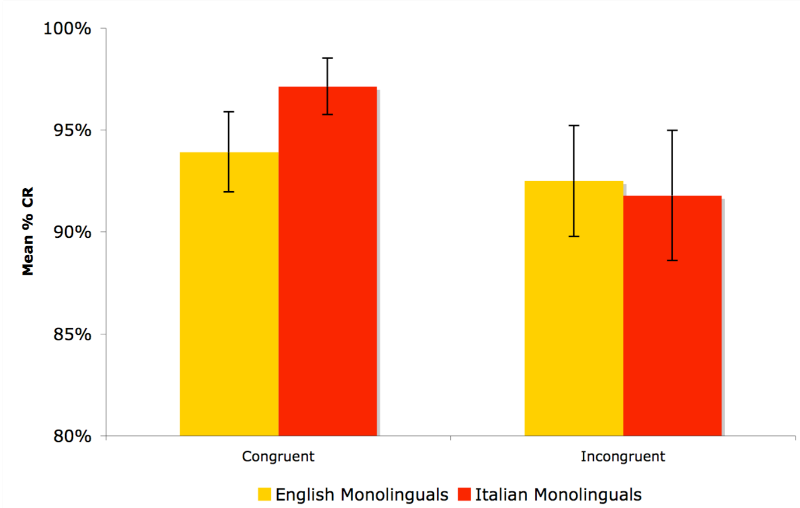


Figure 7.19: Percent correct responses (CR) with congruent and incongruent trials in the Simon task: comparison between English and Italian monolinguals.

Bilinguals vs. monolinguals

The two monolingual groups were collapsed together and compared with the bilinguals. Figures 7.20 and 7.21 displays their performance for reaction times and accuracy, respectively.

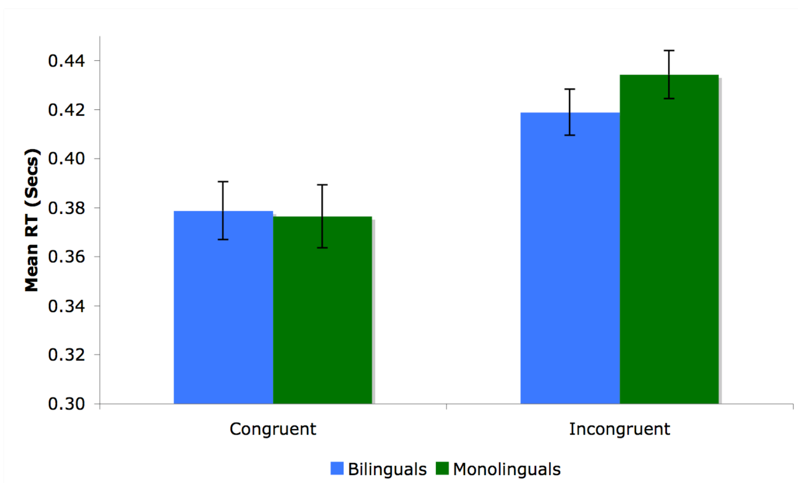


Figure 7.20: Mean RTs and standard errors for congruent and incongruent trials in the Simon Task: bilinguals vs. monolinguals comparison.

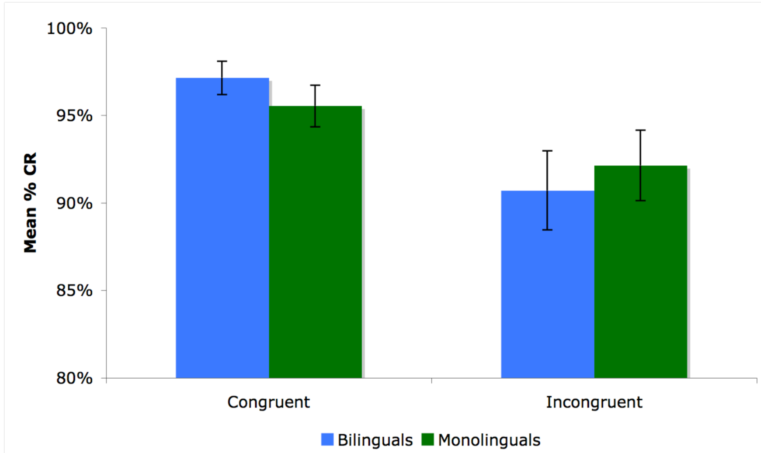


Figure 7.21: Mean percent of correct answers and standard errors for congruent and incongruent trials in the Simon Task: Bilinguals and Monolinguals comparison.

The reaction times on valid trials and percent correct responses were examined with a two-way ANOVA for language group, and congruency. There was a main effect of congruency for both reaction time and accuracy, reaction times: $F(1,56)=74.604$, $p<.001$, $\eta^2=.571$; accuracy: $F(1, 56)=10.311$, $p=.002$, $\eta^2=.155$, indicating that bilinguals and monolinguals were faster and more accurate with congruent trials than incongruent trials. There was no main effect of language group for reaction times, $F(1,56)= .317$, $p=.576$, $\eta^2= .006$, and accuracy, $F(1,56)=.005$, $p=.946$, $\eta^2=.001$, and no interaction between language group and congruency, reaction times: $F(1,56)= 2.715$, $p=.105$, $\eta^2=.046$; accuracy: $F(1, 56)=1.164$, $p=.285$, $\eta^2=.020$, indicating that the two language groups did not differ in the Simon task either in terms of reaction times and accuracy. A post hoc power analysis conducted using the software package G*Power (Erdfelder et al., 1996) revealed that the power to detect obtained effects at the 0.05 level was 0.61 in prediction of differences in the Simon task between bilinguals and monolinguals. A priori power analysis with power (1 - β) set at 0.80 and α = 05, two-tailed showed that sample size would have to increase up to N=264 in order for group differences to reach statistical significance at the 0.05 level. The implications from these results are discussed in the Conclusions section below.

In sum, there was no evidence for a bilingual advantage in executive function when performing a non-verbal task. Attentional advantages, if real, are confined to the language system.

Predictors of bilingual performance on the diotic listening task

Proficiency and high cognitive load

Bilinguals' individual scores in the sentence interpretation task were regressed against cognitive-academic level of proficiency in English obtained from the BVAT. To begin, one condition was used that was taken to be most diagnostic of the bilingual advantage. This was sentence interpretation accuracy for English (weaker language) non-canonical sentences with Italian (native language) interference. Regression analysis inspected for outliers (Cook & Dennis, 1977) revealed that level of proficiency in L2 makes a significant contribution (p=.001) to predicting sentence interpretation in high cognitive load. Moreover, as shown in Figure 7.22, proficiency in English was also a reliable predictor when the task was performed in Italian with Italian interference (p=.017).

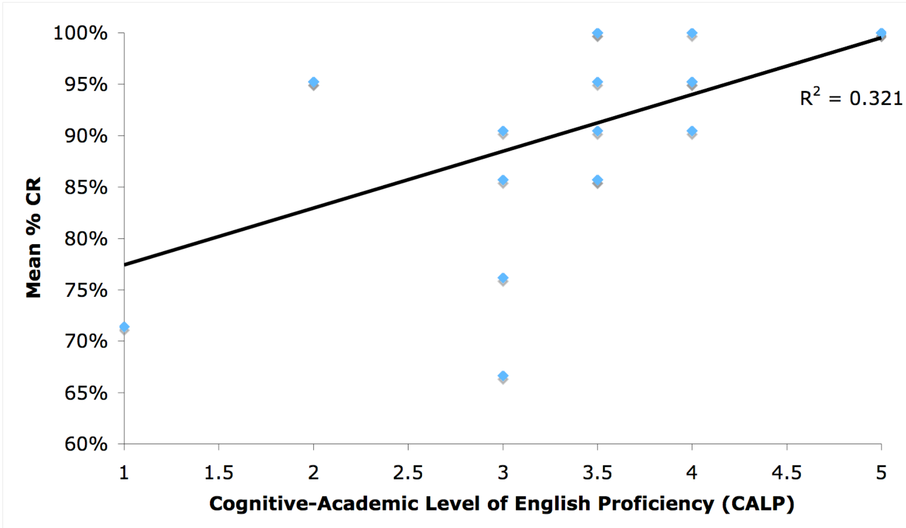


Figure 7.22: Bilinguals' individual performance in the sentence interpretation task (Italian non-canonical sentences with Italian interference), correlated with the BVAT Cognitive-academic level of proficiency in L2.

Spearman's rho correlation (robust to outliers) confirmed this relationship (*rho*=.539, *p*=.014). In summary, the greater the bilingual proficiency, the better able are bilinguals to screen out competing, task irrelevant, L1 speech.

Non-Verbal ability and Cognitive Control

A multiple regression was carried out to investigate the contribution of the bilinguals' verbal and non-verbal ability to predicting sentence comprehension. The two independent variables used in the model were: (1) *Non-verbal*: reaction times for incongruent trials in the Simon Task; (2) *Verbal*: the cognitive-academic level of English proficiency (CALP). The dependent variable was the sentence interpretation accuracy for Italian non-canonical sentence with Italian interference. Table 7.4 presents the results of the model, indicating that non-verbal ability was not a significant predictor for cognitive control advantage in the sentence interpretation task (*p*=.342). On the contrary, proficiency in L2 explained 35.7% of the variance.

Table 7.4: Multiple regression analysis. Performance with incongruent trials in the Simon task (Non-Verbal) did not predict a cognitive control advantage in the sentence interpretation task, whereas proficiency (Verbal) in L2 was a reliable predictor.

	B	**SE B**	**β**
Constant	.573	.164	
Non-Verbal	.329	.336	.590
Verbal	.058	.019	.192**

R^2=.357; **p=.008.

Both analyses repeated computing the task-efficiency scores in the sentence interpretation and the Simon Task, yielded to the same results.

7.4 Discussion

The current experiment aimed to investigate the hypothesis that the bilingual experience facilitates directing attention to an attended speaker in the presence of language interference using a sentence interpretation paradigm. The performance of Italian/English late adult bilinguals was compared to, respectively, Italian monolinguals and English monolinguals. Bilingual competence in both L1 and L2 was also assessed using two lexical decision tasks, one online and one offline, and a standardised test, the Bilingual Verbal Ability Tests (Muñoz-Sandoval, Cummins, Alvarado, & Ruef, 1998). Combined results from the lexical decision tasks showed that Italian/English bilinguals had approximately equivalent performance to Italian monolinguals. English monolinguals outperformed bilinguals in reaction times and accuracy with both word and non-word stimuli. Thus, bilinguals were more competent in their native language, Italian, than English. The result of standardised tests indicated that the bilingual participants' level of cognitive-academic proficiency in English ranged from low to high levels of proficiency.

For the sentence interpretation task, the two monolingual groups had similar performance. They were both more distracted by their native language interference, which in turn lowered their accuracy rate in comprehending target sentences, especially those having a more difficult grammar constructions (O-S-V non-canonical sentences). This finding seemed to support the cognitive load view (Lavie, 1995). Although stimuli were different from the ones used in Lavie's studies, a higher load on working memory (i.e., the analysis and comprehension of infrequent sentences) seemed to be more permeable to interference from the most familiar language.

However, this was not to the case for bilingual speakers. Evidence from the language assessment indicated that they were more competent in their native language

(Italian) and also had considerable variability of English proficiency, their performance in the sentence interpretation task was not different from the English monolingual group. Bilinguals were more efficient at directing their attention on the target sentences, showing a greater resilience to interference, which in turn seemed to compensate their lack of competence in English language. However, the most interesting findings compared bilinguals with Italian monolinguals. The two groups belonged to the same population with the only notable difference being that the former moved to the UK and the latter live in Italy. Bilinguals outperformed Italian monolinguals on non-canonical sentence interpretation in the presence of native language interference, that is, when the cognitive demand was higher.

The study failed to replicate a bilingual advantage in a non-linguistic executive function task, previously reported in the literature (Bialystok, 2006; Bialystok, Craik, Klein & Viswanathan, 2004; Martin-Rhee & Bialystok, 2008). When bilinguals and the two monolingual groups were compared using a common paradigm in bilingual research, the Simon Task, they showed equal performance. This does not seem to support the hypothesis for a convergence of cognitive mechanism for linguistic and non-linguistic functioning (Bialystok, 2005, 2008). Power Analysis a much larger number of participants (N=262) was required in order to reach statistical significance. This is in contrast with prior work (e.g., Bialystok et al., 2004), where statistical significance and large effect sizes using the same paradigm were obtained comparing 20 bilingual and 20 monolingual adults. On the contrary, this study showed a language-specific advantage for bilingual speakers only in sustaining attention to an auditory verbal task.

On the assumption that their English proficiency is a proxy for experience in using a language and in controlling its use in competition with the other language, I looked to see if the more proficient showed less interference. The cognitive-academic level of proficiency (CALP) from the BVAT was regressed against the bilinguals' performance when comprehending both English and Italian sentences in the face of native (L1) interference. It is worth noticing that the CALP index combines lexico-semantic abilities and does not include syntactic abilities. However, as explained in Chapter 4, the CALP is an index of L2 proficiency at an academic level. Thus, no other test of receptive grammar (e.g., the TROG-2) was performed and it was assumed that syntactic abilities, although not measured directly, are not an issue at such an academic level of language skills. Additionally, many studies in bilingual research measure and correlate proficiency to performance either using non-standardised tests or just self-reported assessment. Therefore, the BVAT-CALP provides a far more reliable measure of L2 proficiency.

Regression analyses showed that more proficient English speakers showed less interference: they were not only more accurate responding to non-canonical English sentences in the face of Italian interference but also when comprehending Italian non-canonical sentences in the face of Italian interference**.** Experience in language control may then be crucial to any bilingual advantage in moderating the effects of sentence-level interference during the comprehension of both native and non-native languages.

By contrast, performance in the non-verbal executive function task was not a good predictor.

7.5 Conclusions

Despite the fact that all groups were exposed to the same energetic masking, bilinguals were better able than Italian monolinguals to filter out the linguistic interference, showing an advantage at directing, sustaining attention, and inhibiting task-irrelevant stimuli in the sentence interpretation paradigm. However, no group showed a difference in the non-verbal executive function task, the Simon task, questioning on its sensitivity and replicability of results in similar circumstances. However, a bilingual advantage in non-verbal cognitive control in adulthood was shown, for example, using the ANT task (Costa, Hernandez, & Sebastián-Gallés, 2008) and involving a larger number of participants (N=100). The failure to obtain robust and consisting results across different paradigms tapping components of the cognitive control system should be considered as a signal for caution and a further motivation for researchers to investigate this topic.

This study showed that the diotic listening paradigm applied to bilingual research can shed new light to understanding crucial cognitive processes. In the next chapter another diotic listening paradigm was used to explore at what level in the comprehension system a bilingual speaker can screen out a task irrelevant message.

Chapter 8

Study 4: Executive function and inhibitory control

Attention to and switching between perceptual properties of the speech input

8.1 Introduction

The previous study showed that Italian/English bilinguals had an advantage over Italian monolinguals at suppressing language interference in a sentence interpretation task. In particular, bilinguals outperformed Italian monolingual speakers when the task was most demanding, that is, identifying the agent of non-canonical Object-Verb-Subject Italian sentences in the presence of native language interference. They showed an advantage at directing, sustaining attention, and inhibiting task-irrelevant stimuli in linguistic task, especially when the cognitive load was higher (Lavie, 1995). However, the previous design did not allow us to investigate at what level in the comprehension system a bilingual speaker is screening out a task irrelevant message as target sentences and interference sentences were not time-locked. Thus, the analysis of reaction times could not help us establish when the inhibition of irrelevant information had occurred. Following on logically from our previous study, the performance of a group of late Italian/English bilinguals and a group of age-matched English monolinguals was compared in a modified diotic listening task. This new task presented some similarities with the non-verbal visual paradigm that was already used in Studies 1 and 3 to investigate executive function in children and adults, the Simon task. Basically, two auditory stimuli, the words *right* and *left* replaced the two visual stimuli, the colours *red* and *blue*, used in the Simon task. The two words were used as instructions eliciting an appropriate motor response, that is, pressing either the right or the left button on a keypad. The auditory stimuli were uttered by a man and a woman and presented simultaneously in both ears at each trial (i.e., the man's and the woman's voice together). The appropriate motor response was cued by a visual stimulus, a woman's face or a man's face, singularly appearing at the centre of the screen. Participants were required to: (1) focus on the gender (first visually, then acoustically); (2) ignore the competing message or distractor (inhibition component); (3) constantly shift their attention between the two genders (cognitive flexibility component), and; (4) respond accordingly to what the voice said by pressing either the right or the left button on a keypad.

Compared to the sentence interpretation task, this new diotic listening paradigm was made easier by using simple instruction stimuli (i.e., right/left) instead of complex sentences. In another respect it was made harder by introducing an unpredictable switching component modeled from the bilingual lexical comprehension literature (Meuter & Allport, 1999; Thomas & Allport, 2000), to assess cognitive flexibility. Moreover, in order to address the main question of this study, that is, at what level of the comprehension system participants could screen out linguistic interference, I manipulated the auditory interference by creating *non-conflicting* (i.e., both male and female saying the same word) and *conflicting* trials (i.e., male saying *right* and female saying *left* or vice versa). The logic behind this manipulation is simple: if the interference is screened out at the beginning of the comprehension system, participants should show equal performance with both conflicting and non-conflicting trials. In other words, interfence will not cause any disruption to comprehension and motor response will always be appropriate. However, if there will be a facilitation for non-conflicting trials and a disadvantage for conflicting trials, that would mean that interference does affect comprehension. This interaction could also show that the gate of inhibition may occur later rather than erlier in the comprehension system.

Short runs of 2, 3 or 4 trials with alternate gender were presented. A schematic illustration of the task is provided in Figure 8.1. Response times and error rates were recorded.

A recent study by Soveri, Laine, Hämäläinen, and Hugdahl (2010) showed a bilingual advantage in attentional control using a forced-attention dichotic listening task with syllabic stimuli (Hugdahl & Andersson, 1986). Pairs of syllables were presented at the same time, one to the left and one to the right ear. The participants were asked beforehand to focus either on the left or the right ear, listen to the stimuli and report the target syllable. Early Finnish-Swedish bilinguals outperformed Finnish monolinguals in reliably reporting more target syllables both from the right and the left ear (Cohen's *d*=1.0). The authors concluded that these findings support previous research indicating that bilingualism can enhance executive function, in particular inhibition of irrelevant information (e.g., Bialystok, 1999; Bialystok et al., 2004; Bialystok et al., 2006; Costa et al., 2008; Carlson & Meltzoff, 2008). It is worth noticing, however, that as with Study 3, the attentional effects were operating within the language system.

Another recent study by Bialystok and Viswanathan (2009) not only confirmed a bilingual advantage in inhibitory control, but also in the cognitive flexibility that underlies task switching. They used a computerised visual task, the anti-saccade paradigm, in which the participants, children ranging from 7 to 9 years of age, were required not only to inhibit their response after a conflicting cue, but also to switch between different conditions. Bilingual children outperformed monolingual peers in terms of reaction times but not for accuracy; they were faster at ignoring irrelevant information and showed a smaller cost for switching between trials than monolinguals (Cohen's d=0.9 and 2.0, respectively).

In this current study, it was predicted that if the irrelevant information is inhibited early in the comprehension system, that is, the distractor has no effect and participants always perform an appropriate response on the right or left button of the keypad, the performance with conflicting and non-conflicting stimuli should be equal. However, participants might be slower and less accurate with switch trials if perceptually based inhibition is not immediately in place. By contrast, if the gate of inhibition occurs later in the comprehension system, the reaction time for conflicting trials should be greater. In other words, the comprehension of the word and the subsequent action to perform are disrupted by interference.

In line with Bialystok and Viswanathan (2009), monolinguals should exhibit less skill than bilinguals at inhibiting irrelevant information and switching between trials, particularly as this task remains within the language system.

8.2 Methods

Participants

Thirty-six healthy adults participated in this study. Eighteen of them were Italian/English late bilinguals living in the UK (mean age 31.0, SD=7.4, range = 21.2-42.0, 4 males). Six of them had already participated in the sentence interpretation task. They were all native speakers of Italian and they were first exposed to English after the age of 10.0. Their performance was compared with a control group of 18 English monolinguals living in the UK (mean age 30.0, SD=4.4, range= 20.5-42.0, 6 males). Both bilingual and monolingual participants signed an informed consent and did not report any visual, auditory or neurological impairment.

Design

The experiment was a 3-factor mixed design. The within subject independent variables were type of stimuli at two levels (conflicting and non-conflicting), and trial type (switch and non-switch). The between subject independent variable was language group (bilinguals v. English monolinguals). The dependent variables were the participants' reaction times and accuracy. A third within subject factor, input type (male's voice, female's voice) was used in a post hoc analysis.

Stimuli

Stimuli were both visual and auditory. The visual stimuli represented two pictures taken from the Internet, one of a man and one of a woman. Single pictures were 7cm by 9cm and displayed one at a time at the centre of the computer screen, as shown in Figure 8.1. The auditory stimuli consisted of two words, "right" and "left" that were recorded by native speakers of British English, one female and one male, using the MacBook built-in microphone. The waveform of each word was then edited, converted into a 16-bit 44.125 kHz mono sound file in Audacity 1.2.5 for Mac, and saved in .wav format. Both stimuli were then normalised to a root mean squared amplitude of 70 dB using Praat software (Boersma & Weenink, 2010). The task was programmed using Matlab for Mac.

Equipment

The experiment was presented on a MacBook 13' laptop computer using Matlab. The stimuli were presented through Sennheiser EH-150 headphones. Reaction times and accuracy were recorded in Matlab from an USB Logitech Precision game-pad in which only two buttons were enabled, one on the right and one on the left.

Procedure

All participants were tested by the same experimenter and on the same equipment in a quiet environment at the Centre for Brain and Cognitive Development, Birkbeck College, London. Each session started with a short test to establish if the participants could successfully perform an auditory-motor task. This baseline measure consisted of 32 'ping' sounds, each 0.3 seconds long, which were adapted from the alert sounds native to Mac OS 10.3. Participants pressed either the left or right button on a response keypad corresponding to the ear in which they heard a sound. Participants were asked to press the button as fast as they could with the thumbs of both hands.

For the diotic listening task, participants were presented with a total of 96 trials featuring either a man or a woman appearing at the centre of the screen. They were instructed to focus on the voice of the gender represented in the picture (visual cue), saying either "right" or "left" (auditory stimuli). Both voices were simultaneously and binaurally presented via the headphones. The visual cue appeared on the screen 500ms before the first switch trials and remained on the screen until the run was completed. Auditory stimuli were presented immediately following the subjects' response up to a max of 4,000 ms after which, if no response, the next trial was presented automatically. Stimuli comprised congruent trials, in which the woman and the man's voices uttered the same words (e.g., *Right/Right*), and incongruent trials, in which the two genders uttered different words (e.g., *Left/Right*). Congruent and incongruent trials were pseudo-randomly arranged in two presentation orders. They were administered for 15 times as *non-switch* and for 15 times as *switch* trials for each gender.

Each session consisted of 8 practice trials and 96 experimental trials split in two parts of 48 each. A fixation cross appearing at the centre of the screen prompted the participants before the experiment started. Stimuli were presented in short runs of same-gender trials for unpredictable presentation. If x was a switch trial, there was a 67.39% that trial $x+1$ would be a switch back into the other gender's voice. If that was not, $x+2$ had a chance of 93.48%, and $x+3$ = 100%.

Participants were instructed to focus on the visual cue (i.e., the man or the woman), and follow the matching auditory prompt by pressing either the left or the right button on the gamepad. They were told to perform the task as fast and accurately as they could. As shown in Figure 8.1 A and B, the images of two beauty icons were chosen in order to make the task more pleasurable, the American actor George Clooney and the German top model Claudia Schiffer. Participants took approximately 10 minutes to complete the task.

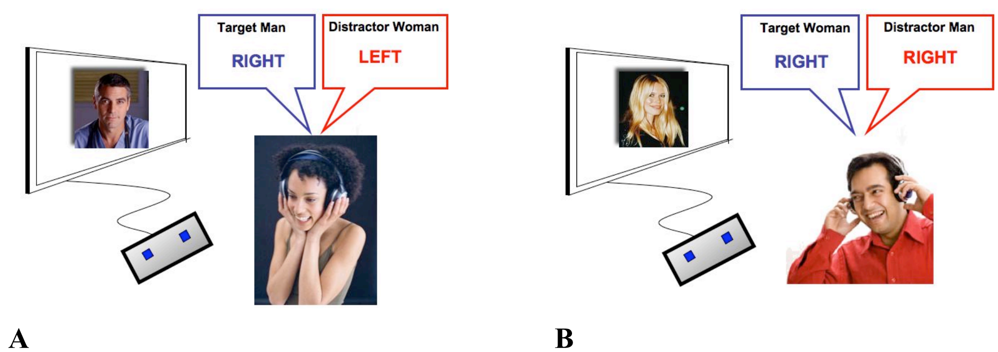


Figure 8.1: An illustration of the diotic listening task. **A**: the participant is focusing on the man's voice following the cue on screen. Subsequently she is hearing two simultaneous voices. The target voice is the man saying "Right". In this case the trial is "Conflicting" because the woman is saying "Left". **B**: in this case the participant is focusing on the woman's voice and listening to a "Non-conflicting" trial.

8.3 Results

The bilingual and the monolingual groups' performance in the non-verbal sounds pre-test was similar: bilinguals had a mean response time of 0.37 seconds (SD=0.09) and 99.0% accuracy (SD=0.02) and English monolinguals had a mean response time of

0.36 seconds (SD=0.08) and 99.0% accuracy (SD=0.02). A one-way ANOVA revealed no significant difference between two groups for response time, F(1, 35)=.244, p=.642, n.s., and for accuracy, F(1,35)=.077, p=.783, n.s. ANOVA also revealed a non significant gender difference in performing the task, RTs: F(1,35)=1.875, p=.180, n.s.; accuracy: F(1,35)=.001, p=.98, n.s. This result indicated that the groups processed non-verbal sounds in the same way. Thus, they could successfully perform an auditory-motor task.

Diotic listening switching task

Individual median reaction times were collected to reduce the influence of outliers and pooled for the bilingual and the monolingual groups. The mean reaction time on correct responses and error rates was analysed with a 2x2x2 mixed ANOVA, for stimulus type (conflicting, non-conflicting), trial type (switch, non-switch) and language group (bilinguals, monolinguals).

For reaction times, there were main effects for all three factors: language group, F(1,34)=5.626, p=.023, η^2=.142, stimulus type, F(1,34)=24.623, p=.001, η^2=.420, and trial type F(1,34)=25.664, p=.001, η^2=.430. There were no interactions between language group and any other factor. As shown in Figures 8.2 and 8.3, both groups were faster with non-conflicting than conflicting trials and with non-switch than switch trials. However, bilinguals were significantly faster than monolinguals.

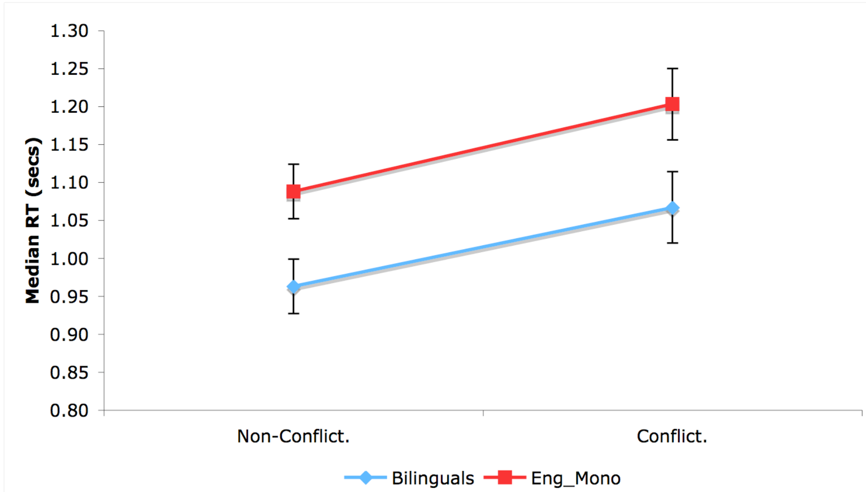


Figure 8.2: Bilinguals and monolinguals' performance with non-conflicting and conflicting trials in terms of reaction times (seconds). The error bars display the standard error of the mean.

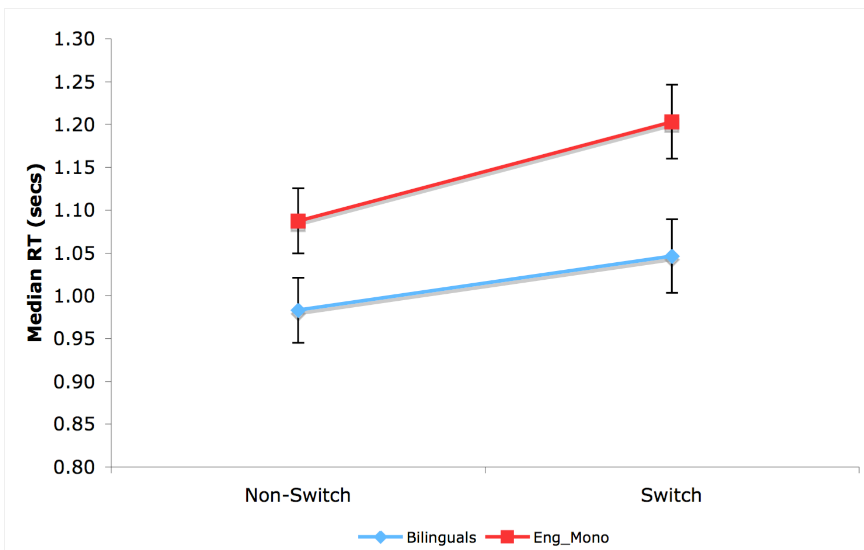


Figure 8.3: Bilinguals and monolinguals' performance with non-switch and switch trials in terms of response times (seconds). The error bars display the standard error of the mean.

For accuracy, the two groups had comparable performance, $F(1,34)=.593$, p=.446,

η^2=.017. There was a main effect of stimuli $F(1,34)=88.147$, $p<.001$, η^2=.722, and trial type, $F(1,34)=65.077$, $p=.001$, η^2=.657. There were no interactions between language group and any other factor. As shown in Figures 8.4 and 8.5, both groups were less accurate with conflicting trials and with switch trials but their overall performance was comparable.

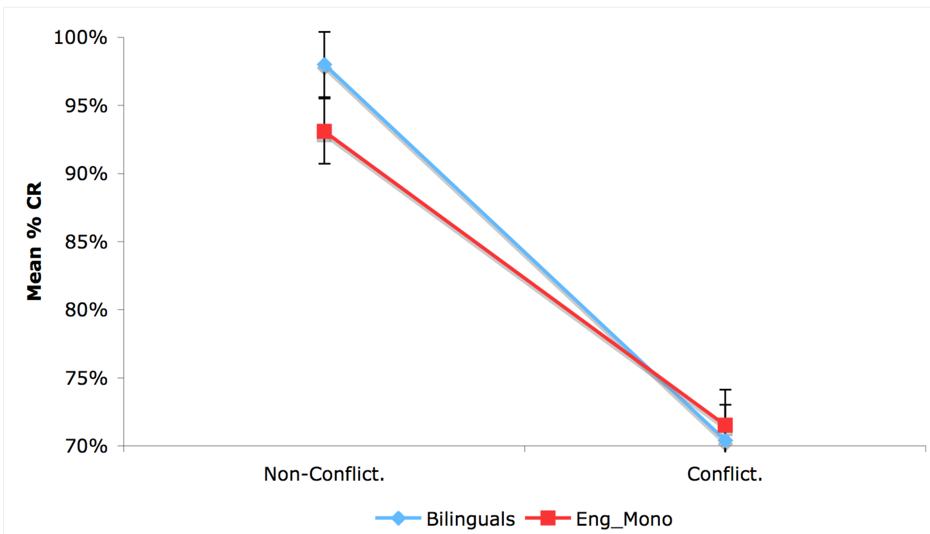


Figure 8.4: Bilinguals and monolinguals' performance with non-conflicting and conflicting trials in terms of accuracy (percent correct responses). The error bars display the standard error of the mean.

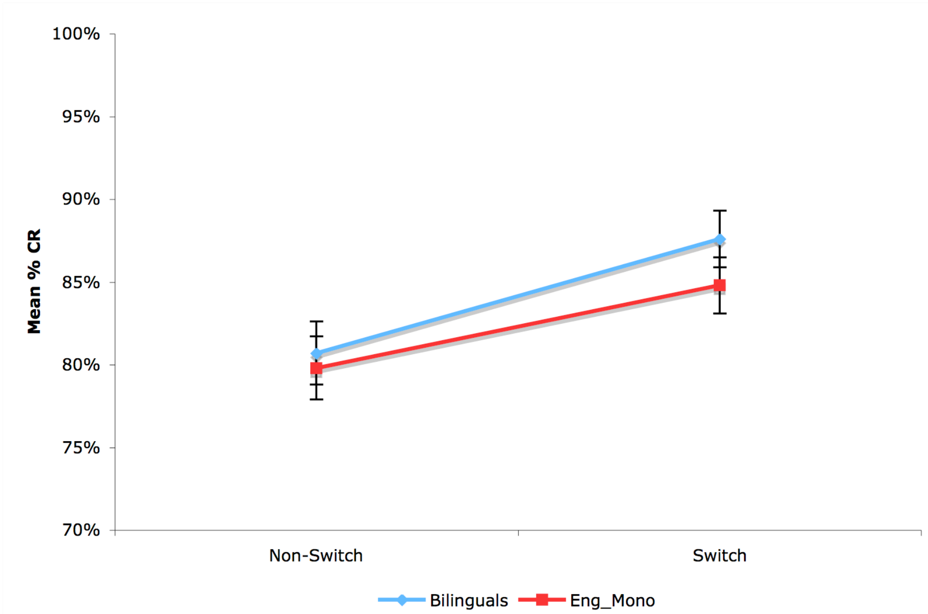


Figure 8.5: Bilinguals and monolinguals' performance with non-switch and switch trials in terms of accuracy (percent correct responses). The error bars display the standard error of the mean.

Summary

Both groups showed greater latencies with conflicting trials, supporting the hypothesis that inhibition occurred later in the comprehension system. Both groups also showed a switching cost between trials. Bilinguals were reliably faster than monolinguals in all conditions. However, monolinguals did not show any reliable disadvantage over bilinguals at inhibiting irrelevant information and switching between trials. In terms of error rates, the groups' performance was comparable, indicating that low cognitive load did not cause any difference between bilinguals and monolinguals.

Shifting between different input sources

All participants reported more difficulty listening to the male's voice. I further explored the data with a 2x2 ANOVA for input type (male, female), and language group (bilinguals, monolinguals). ANOVA confirmed that both groups were significantly faster and more accurate at processing the woman's voice, response times: $F(1,34)=34.316$, $p<.001$, $\eta^2=.502$; accuracy: $F(1,34)=77.637$, $p<.001$, $\eta^2=.695$. As displayed in Figure 8.6, bilinguals were reliably faster but equally accurate at processing both inputs, response times: $F(1,34)=6.490$, $p=.016$, $\eta^2=.160$; accuracy: $F(1,34)=.593$, $p=.446$, $\eta^2=.017$. A marginally significant interaction, $F(1,34)=3.446$, $p=.072$, $\eta^2=.092$, showed that bilinguals were faster than monolinguals when the input source was the male's voice. Figure 8.7 shows that both groups' error rates were approximately the same, $F(1,34)=1.084$, $p=.305$, $\eta^2=.031$.

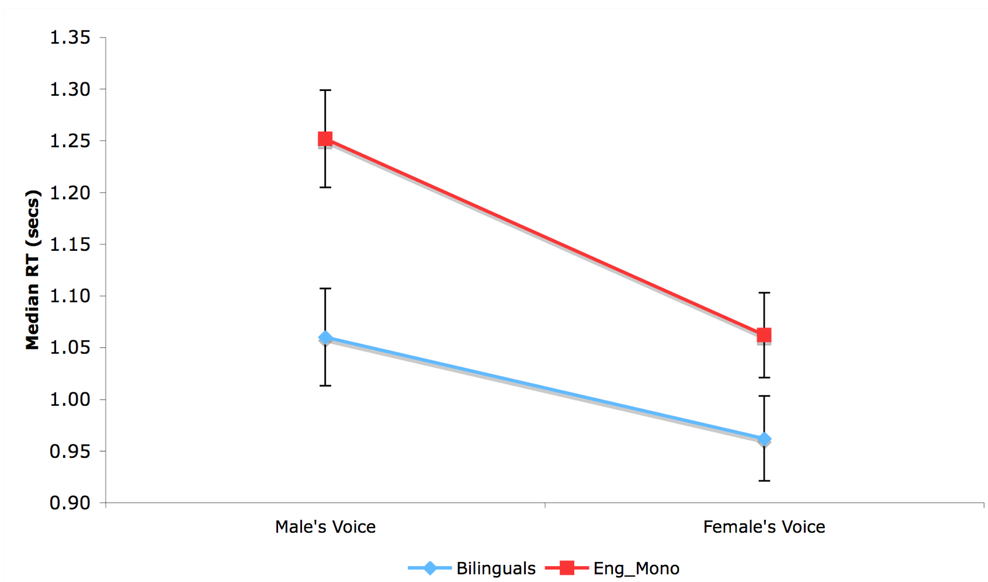


Figure 8.6: Bilinguals' and monolinguals' performance between the two input signals (male and female voices) in terms of reaction time (seconds). The error bars display the standard error of the mean.

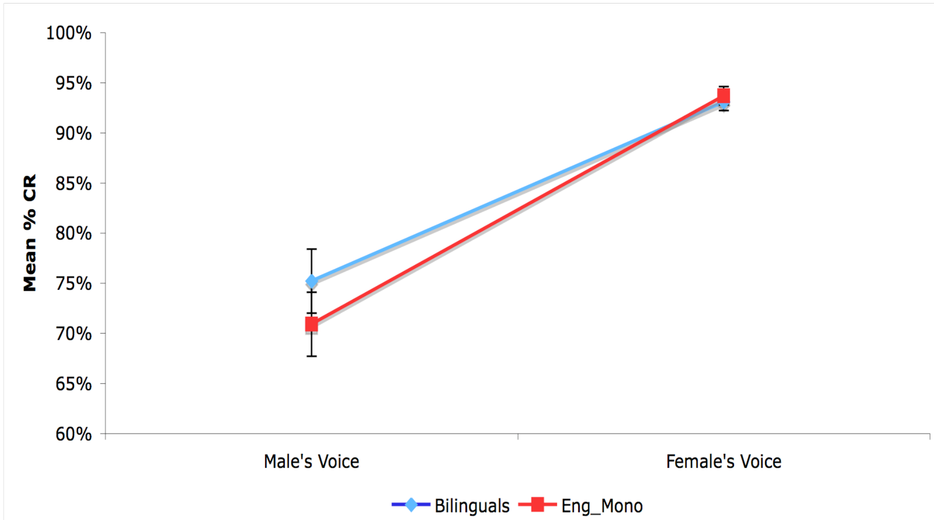


Figure 8.7: Bilinguals and monolinguals' performance between the two input signals (male's and female's voice) in terms of accuracy (percent correct responses). The error bars display the standard error of the mean.

A further contrast compared the two groups' performance considering only the most demanding condition, i.e., switching between conflicting and non-conflicting trials when the input was the man's voice. As shown in Figure 8.8, the groups showed a switching cost with both conditions. Monolinguals were numerically slower when switching with conflicting trials. However, the interaction between group and trial type with conflicting stimuli was non significant, $F(1,34)=1.903$, $p=.177$, $\eta^2=.053$.

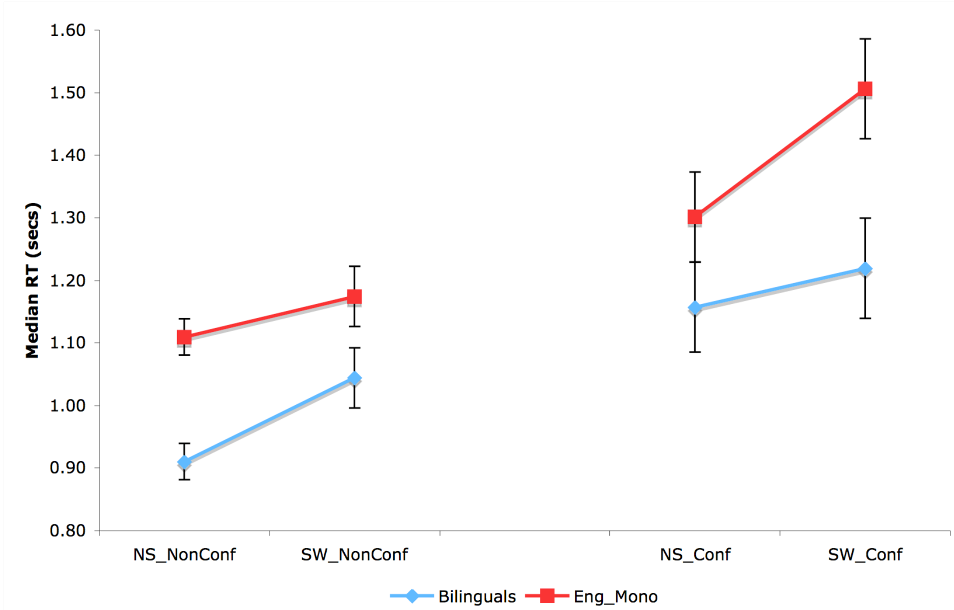


Figure 8.8: Bilinguals and monolinguals' interaction in terms of reaction times (seconds) between non-switch (NS) and switch (SW) trials with conflicting (Conf) and non-conflicting (NonConf) stimuli when the input source was the male's voice. The error bars display the standard error of the mean.

Summary

Overall, these results indicated that the groups had comparable performance in terms of accuracy: bilinguals and monolinguals made more mistakes with conflicting trials than non-conflicting trials. However, bilinguals were generally faster than monolinguals at processing either switch or non-switch conflicting and non-conflicting trials. A closer look at the data indicated that attending to the male's voice increased the task difficulty: both groups were slower and less accurate in this condition.

8.4 Discussion

In this study, I aimed to further investigate the findings reported in Chapter 7 in which bilinguals showed an advantage over monolinguals when processing sentences in the presence of language interference. A new diotic listening paradigm was devised in order to address the question of when in the comprehension system a bilingual speaker can screen out a task-irrelevant message.

All participants were first tested with a measure of reaction time when hearing a simple non-verbal sound in which no difference was found between language groups. For the diotic listening task, the results confirmed an overall bilingual advantage at processing the target stimuli, either conflicting or non-conflicting, regardless of the input characteristics. Bilinguals always outperformed monolinguals in terms of reaction time, but both groups had equivalent accuracy. However, this study failed to show evidence for a bilingual advantage over monolinguals at inhibiting irrelevant information (as defined by conflicting input from the two voices). A closer analysis of the data provided some evidence that bilinguals performed better than monolinguals when the cognitive demand of the task was higher; a marginally significant interaction, showed that bilinguals were faster than monolinguals when the task presented an increased level of difficulty, that is, when the input source was the male's voice. A similar pattern was observed in the previous study in which bilinguals outperformed Italian monolinguals when the cognitive load was higher (i.e., when identifying the agent of a non-canonical sentence in the presence of native language interference). Overall, both groups' performance was generally worse with conflicting than non-conflicting trials. This result provided evidence for a later rather than earlier gate of inhibition.

8.5 Conclusions

In summary, the late Italian/English bilinguals demonstrated a clear advantage in reaction times but not in accuracy. This advantage neither interacted with the conflict effect nor with the switching effect. Although there was no evidence for a reliable advantage over monolinguals in inhibiting irrelevant information (e.g., Bialystok, 2001, Bialystok & Viswanathan, 2009), these results clearly showed that bilinguals selected their attention to the target stimulus more efficiently (Costa et al, 2009; Bialystok 2010). This provided further evidence in support of the interpretation that the conflict for selection between two active languages is central to enhancement of executive control in bilinguals.

So far, I have explored bilingual language development and executive function in early bilingual children and language comprehension and selective attention in adult late bilinguals. This research project will now cover what is probably the least explored dimension of bilingualism: language production.

Chapter 9

Study 5: Control effects in language production

9.1 Introduction

In this chapter I investigate bilingual switching in language production of visually presented Italian and English words. As shown in Chapter 3, the bilingual adults who took part in this research project regularly used both languages and the vast majority of them (87%) reported switching between their known languages in everyday life. But how do bilingual speakers control the use of their two languages? When they speak in one language is the other active in parallel? How do they manage the competition in selecting one language over another? These fundamental questions are at the centre of a still unresolved debate in bilingual research. The main issue is not in the bilingual ability to control two languages per se, rather to control the use of L1 over L2 and vice-versa without showing any obvious disfluency (e.g., Ransdell & Fischler, 1987). Understanding the mechanisms that allow bilinguals to perform such tasks could help reveal important processes about cognition in general (Abutalebi & Green, 2008).

Lexical access in speech production: from concepts to words

What is the process that makes the connection between an idea and the word that represents this idea? Models of monolingual language production (e.g., Fromkin, 1973; Levelt, 1989), generally distinguish two systems: (1) a conceptual system containing word knowledge in the form of non-verbal representation, and (2) a mental lexicon, which contains syntactic, phonological and semantic characteristics. Thus, when a monolingual speaker sees a picture of a *dog,* a representation of it will be activated and selected in the conceptual system. However, this seemingly simple task may present a degree of difficulty. These models assume that many other concepts become activated and will compete for selection. For example, the target concept of dog will activate other related concepts, i.e. cat, bark, etc. This conceptual activation spreads to the lexical system, which is responsible for the selection and ultimately for the phonological production of the word *dog* among those candidates. In Levelt's (1989) model, a monitoring process is proposed which is responsible for detecting whether the meaning of the word and the conceptual representation are matched. If a mismatch is detected either before or after articulation, a repair will be necessary.

Bilingual lexical access: Two languages, one concept

Cognitive models of bilingual language production tend to assume the existence of a single conceptual representation for the two languages, linked to two different lexical representations. One of the most influential model, the Revised Hierarchical Model (Kroll & Stewart, 1994) postulates that when a second language (L2) is acquired it is strongly connected to the more dominant language (L1). This link is represented in Figure 9.1 with a solid line. L1 is connected to L2 with a weaker line. The connection between L2 and concepts is weaker as well and lexical access in L2 needs to be mediated by L1. As proficiency in L2 increases, the interconnections between both L1 and L2 and L2 and concepts get stronger, so that lexical access in L2 does not always require L1 mediation. However, the model does not provide an explanation as to how a bilingual switches between languages.

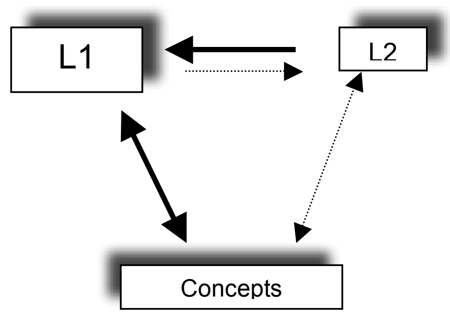


Figure 9.1: An illustration of the Revised Hierarchical Model (Kroll & Stewart, 1994)

Are the two languages both active? Evidence from language comprehension studies.

Research with visual or spoken words recognition and word production has provided convincing evidence that lexical access is non-selective, that is, alternatives in both languages are activated in parallel even when words are processed in only one language (Kroll, Gerfen & Dussias, 2008). An empirical demonstration of this phenomenon is provided using a visual lexical decision paradigm in which participants are asked to decide whether a word appearing on a computer screen is real or not. They are required to press a "yes" or "no" button on the keyboard, and their reaction times and accuracy are recorded. The adaptation of this paradigm to bilingual research exploited cross-language similarity between words. For example, words from different languages may have same orthography and same meaning, others may have the same orthography but a different meaning. The former are called *interlingual cognates* and the latter *interlingual homographs*. An example of cognate is the word *idea*, which has the same spelling and meaning in both Italian and English, but different phonology. An example of homograph is the word *cane*, which in Italian means *dog*. Researchers using this paradigm compare the reaction times and accuracy between these ambiguous words and others that are not ambiguous, that is, words that are unique in each language, or *singles*. In a typical setting, real words (cognates, homographs and singles) are mixed with plausible non-words, that is strings respecting the spelling rules of the language, and participants are asked to respond whether the presented stimuli are real words in a given language or not. The underlying assumption is that when a participant performs the lexical decision task in a monolingual setting (e.g., L2), his/her performance should not be affected by the presence of words with same representations in the other language. However, many studies showed that bilinguals performing the task in their native language are faster to respond when the real word is a cognate (e.g., van Hell & Dijkstra, 2002), and slower to respond when it is a homograph (e.g., Von Studnitz & Green, 2002). These results provided evidence that both known languages are active in parallel.

This conclusion was criticised by arguing that participants knew they were involved in a bilingual research. Thus, they were in a "bilingual mode", that is, the level of activation of their two languages was higher (Grosjean, 2001). However, when the experiment was repeated with participants who were unaware of the researchers' expectations (i.e., they were not told the research was about bilinguals), results confirmed the previous findings (van Hell & Dijkstra, 2002). Another criticism derived from the diversity of stimuli used (Grosjean, 1998). For example, interlingual homographs may have different frequency, i.e., there could be words of more common use in one language but not in the other. If these factors are not controlled, the results might be affected. Dijkstra and colleagues (1998) considered the impact of word frequency on word recognition with Dutch/English bilingual participants. In a first experiment they used an English lexical decision either with high or low frequency Dutch/English interlingual homographs and exclusively English control words. The participants responded equally fast with both types of stimuli. In a second experiment, the authors added exclusively Dutch words maintaining the same task (English lexical decision). Participants responded "no" when presented an exclusively Dutch word, however they were slower with interlingual homograph, especially when their frequency was low. Dijkstra and colleagues (1998) concluded that frequency-depended competition plays a role between the two readings of the homographs when the non-target language could not be ignored.

Further evidence that both languages may be active in parallel has been provided using a picture recognition paradigm and eye tracking technology (e.g., Marian & Spivey, 2003; Ju & Luce, 2004), and with picture-word Stroop (1935) task in speech production (e.g. Hermans, Bongaerts, De Bot & Schreuder, 1998).

How do bilinguals resolve the competition?

The current focus of research interest concerns the specific locus and manner in which this unintended activity is resolved. A possible explanation is the assumption that the non-target language is suppressed through inhibitory processes. One of the most influential models that focuses on bilingual cognitive control in both comprehension and production is the Inhibitory Control Model, or ICM (Green 1986, 1998). The model was designed to explain issues such as how a bilingual translating a word from L2 to L1 avoids naming the word in L2 and vice-versa. As shown in figure 9.2, the model has several components.

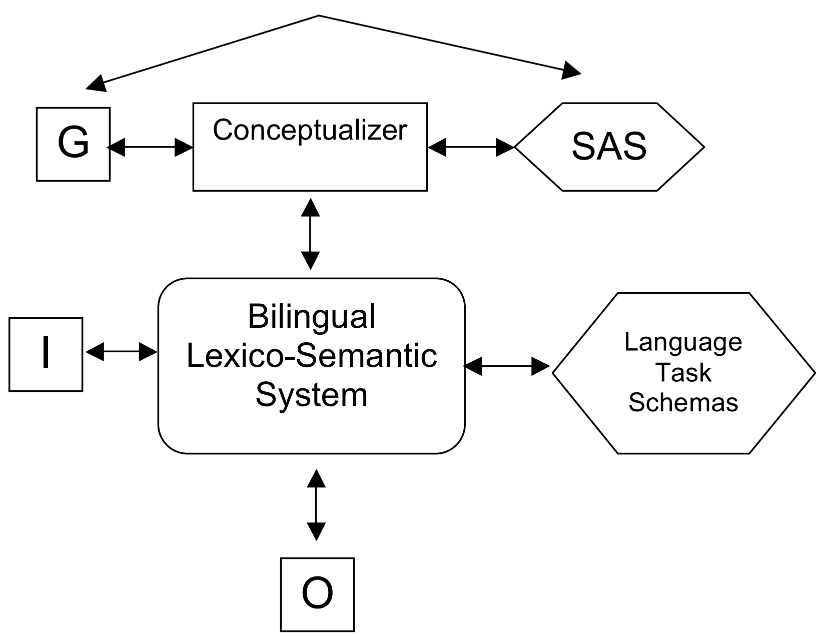


Figure 9.2: The Inhibitory Control Model (Green, 1986, 1998)

The *conceptualizer* and the *lexical-semantic system* are similar to the conceptual store and the bilingual two lexicons already described in the Revised Hierarchical Model (Kroll & Stewart, 1994), although in Green's model the two lexicons are depicted in the same store. Each word is associated to a language specific *lemma,* that is, the information on the morphology, syntax and phonology of each lexical item (Levelt, 1989). The model assumes that during the phase of message planning, a general mechanism is in charge of controlling the speaker's communicative intentions. This mechanism derives from Norman and Shallice (1986) model of action, which, according to the ICM, have much in common with language as a form of communicative action. In order to carry out the action, voluntary control is required. Green explained this concept borrowing the term *schema*, a mental device that individuals construct or adapt on the occasion in order to achieve a specific goal, or task. When a task, e.g., how to make an espresso, has been already performed, it can be retrieved from memory and adapted to a different task, e.g., how to make tea. Existing schemas imply an automatic performance of certain acquired skills. However, novel tasks need novel schemas, which require a voluntary controlled action modulated by a supervisory attentional system (SAS). In the ICM, the task schemas (e.g., producing speech or translating from L1 to L2) in turn work together with the lexico-semantic to determine the output (O). It is the task schema that modulates the amount of activation of the different lexical entries and control the language output by inhibiting or activating different representations. Thus, the ICM predicts the existence of an inhibitory system that suppresses the activation of the language not-in-use. Inhibition can occur either at the schema level or at a lexical level, where specific language tags may be suppressed. For example, when performing a bilingual lexical decision task the participants can continue using a "lexical decision schema", however, they need to wait until the appropriate language tag is activated (e.g., a colour cue associated to the language to be used). Green (1998a, p.74) predicted that this would have minimal impact in terms of switch cost as compared to a larger cost when shifting between schemas occurs. The issues associated with switch costs are covered in the next paragraphs. The model also predicts that language activation is non-selective, that is, the conceptual/semantic components activate lexical entries in both languages. Once activation in the target language is in place, the non-target language is inhibited. Finally, the model predicts that inhibition is reactive, that is, the amount of time needed to switch increases if the level of inhibition increases. Thus, the more activation there is of words in both languages, the greater the inhibition will be for the non-target language. Individual levels of proficiency modulate switch costs: competition is expected to be greater for high proficient bilinguals, who will in turn show more inhibition than less proficient bilinguals (Green 1998b). However, less proficient bilinguals will experience longer latencies when switching back into their dominant language (L1) as it is predicted that L1 requires more inhibition than L2 (Green 1998a).

Inhibition or increased activation? Evidence from switching in production paradigms

The ICM provides one possible theoretical frame to explain bilingual language selection, but alternatives are also currently under debate. For example, La Heij (2005) proposed that the intention to speak one language over the other occurs at the conceptual level and it suffices to resolve competition. According to this view, only a single concept is available for subsequent encoding. The author provided experimental evidence for this claim using a picture versus word distractors in a translation Stroop task (Bloem & La Heij, 2004; Bloem, Van Dem Boogaard & La

Heij, 2004). In this task, participants are required to translate words in the presence of semantically related distractors (words or pictures). When the distractor is a word participants' performance was worse (Stroop effect). However, when the distractor was a picture there was a facilitation rather than interference. According to the authors, the dissociation between effects of picture vs. word distractors can be explained in terms of a conceptual selection model: a lexical representation decays more quickly than a conceptual representation. Thus, only one single target is selected.

Costa and Caramazza (1999) reported a series of experiments in which Spanish-English bilinguals performed a cross-language variant of the picture-word Stroop task in which they were asked to name pictures in one language while ignoring distractor words appearing either in the same or other language. The results showed that there was a facilitatory effect (i.e., faster and more accurate) when the picture and the word were in the same language. Contrary to expectations, there was also a facilitatory effect when the distractor words were in the non-target language. The authors interpreted these results in terms of a language-selective lexical access; if two lexical candidates compete for selection, the translation distractor should have produced interference, that is, slower reaction time and less accuracy, rather than facilitation. Thus, competition may only occur within the target language (Costa & Caramazza, 1999).

One of the most used paradigms to tap in bilingual lexical access and language selection is the language-switching task. In this task, bilingual participants are asked to name a stimulus appearing on a computer screen either in their L1 or L2. Stimuli could be words, pictures or digits. A cue, generally a different colour surrounding the stimulus, one for each of the two languages, prompts the participants when L1 or L2 must be used. Stimuli are usually presented in small runs with either a predictable switch (e.g., shift between languages every two trials, where the first is a switch and the second is a non-switch – e.g., Roger & Monsell, 1995) or an unpredictable switch (e.g., language shifts occur randomly – e.g., Meuter & Allport, 1999). Participants' reaction times and accuracy are recorded and the difference between switch and non-switch trials, the switch cost, is computed.

On a general cognitive perspective, a switch cost is explained in terms of task schema, which was described above (Norman & Shallice, 1986). Allport and colleagues (1994) provided a theoretical account of switch costs in terms of carryover effect from the previous schema into the new one. The authors also described an intriguing phenomenon: when participants where required to switch between two tasks that differed in difficulty (e.g., word reading and colour naming to incongruent Stroop (1935) stimuli), the switch cost was *asymmetric*. Basically, despite participants were overall faster in naming words, they exhibited a lesser cost when switching into colour naming (more difficult task) and a higher cost when switching into word naming (easier task).

Switching languages naming digits

Evidence in support of the Inhibitory Control Model was obtained with various paradigms involving speech production (e.g., Lee & Williams, 2001; Levy, McVeigh, Marful, & Anderson, 2007). However, Meuter and Allport (1999) provided perhaps the first empirical evidence in favour of inhibitory processes in bilingual speech production. They used a switching in language production paradigm to measure the latencies for trials preceded by a same-language response (non-switch) or by a different language response (switch). Bilingual participants speaking a variety of European languages at different degrees of proficiency were asked to name digits appearing singly on a computer screen. The numbers, from 1 to 9, were surrounded by a coloured rectangle functioning as a language cue. For example, if the colour was *blue* the number had to be said in English; if *red* in French. The languages were alternated in a way that participants could not fully predict when a switch could occur (unpredictable switching paradigm). Meuter and Allport (1999) found that the switching cost, that is, the difference in latency between non-switch and switch trials, was higher when participants switched from the less dominant (L2) to the more dominant (L1) language than viceversa. This result was interpreted in support of the Inhibitory Control Model: the non-target language is suppressed when speaking in the target language. However, the observed asymmetry in switching cost also supports the notion that *reactive* inhibition is proportional to the level of activation of the non-target language. In this case, a dominant L1 may require a stronger inhibition, which in turn may result in a higher cognitive effort for its reactivation. Conversely, when switching from L1 to L2, the switching cost is reduced because when speaking in the more dominant language there is no need to inhibit an already weak L2. Meuter and Allport (1999) measured the participants' relative language proficiency in terms of speed at naming numerals in L1 versus L2. On the basis of the results obtained, they arbitrarily split the participants in two groups: (1) Group A were participants with a larger mean difference between L1 and L2 (90 ms), and; (2) Group B were those who had a smaller difference (15 ms). Results showed that Group A, that is, those with a larger difference in language proficiency (less proficient in L2), exhibited a greater switch cost asymmetry than those who showed a smaller difference in relative proficiency (high proficient bilinguals). These findings are in line with the Inhibitory Control Model account, which predicts that when the difference between L1 and L2 proficiency is small, then a similar degree of inhibition should be applied to both languages. Thus, the magnitude of switching cost should be similar in both directions.

Switching languages naming pictures

Costa and Santebastan (2004) further contrasted the performance of high and low proficient bilinguals in a picture-naming switching task. In their first two experiments involving L2 learners and native bilingual speakers of Spanish and Catalan, they replicated Meuter and Allport's (1999) findings, that is, the magnitude of switching cost was larger for low proficient than high proficient bilinguals. However, in subsequent experiments they showed that highly proficient bilinguals who were acquiring a third language (L3), did not show a switching cost asymmetry when performing the task in their stronger L1 and weaker L3. The authors concluded that these findings questioned the prediction of the Inhibitory Control Model: if switching cost asymmetry is the difference in the amount of inhibition applied to L1 and L2, this asymmetry should also be observed when highly proficient bilinguals switch into a third weaker language. However, it is worth noticing that the authors did not use an objective measure of language proficiency, but only self-reported questionnaires. An alternative view was proposed in that proficiency may change the nature of language control. Only low-proficient bilinguals may rely on inhibitory control, whereas highly proficient bilinguals may rely on a language-specific selection mechanism during lexical selection: alternatives from both languages are available during speech planning but they do not compete between each other (Costa, 2005). However, in another picture-naming study by Christoffels and colleagues (2007), cost asymmetry was not found in a sample of low-proficient German/Dutch bilinguals. The authors argued that cost asymmetry might not be only modulated by language proficiency, rather by environmental factors. Participants in that study reported continuous switching between their languages in their daily lives, a factor that could lead to possible advantage in language control that in turn resulted in a symmetric cost (Christoffels et al., 2007).

Switching cost asymmetry was also explored with a paradigm combining pictures and digits. Finkbeiner, Almeida, Janssen, and Caramazza (2006) asked participants to name numbers from 1 to 9 in alternation to a a set of pictures. A colour cue prompted language selection when naming digits, while pictures had always to be named in L1. The authors replicated switching cost asymmetry when participants switched between numbers. However, there was no asymmetry between digits-pictures switches regardeless of the language used naming numbers before the run with pictures. Finkebeiner at al. (2006) claimed that their findings challenged the view for language inhibitory processes as no asymmetry was found when a stimulus (pictures in this case) is named using only one language.

Further evidence in favour of inhibition processes

Philipp and colleagues (2007) further extended the language switching literature using the n-2 paradigm (Mayr & Keele, 2000). In this paradigm, the switch cost is measured for a three-trial run, in which the first trial is, for example, naming a digit in L1, the second naming a digit in L2, and the third naming a digit again in L1. The switch cost of the third trial (where subject switched back into L1), is compared with the third trial in which there was no switching back, e.g., using three trials with three different languages L3-L2-L1. The authors found that naming in L1 in the third trial in the two-language condition, had a greater switch cost than naming in L1 in the three language condition. Although these findings could be interpreted within the frame of the ICM, this asymmetry could also be explained in terms of stronger activation of the weaker

L2, which in turn may cause stronger interference when switching back into the dominant L1.

Overall, current behavioural data do not provide sufficient evidence to determine the specific mechanisms underlying an advantage in inhibitory control.

The rationale for this study

This study expands from Meuter and Allport (1999) using word stimuli instead of digits in a mixed-block unpredictable switching design. Target stimuli were words sharing identical orthography and same meaning in both languages (interlingual *cognates*), words having identical orthography in both languages but pointing to different meanings (interlingual *homographs*), and words that were unique in each languages (*singles*). No words shared phonological forms across languages and word stimuli were balanced by their length, frequency and concreteness within their languages.

Italian/English late bilingual adults participated in this study. Their language dominance was measured with two lexical decision tasks, one online and one offline (see Chapter 7). The Bilingual Verbal Ability Tests (see Chapter 4 for details), was also used to assess the participants' cognitive-academic degree of proficiency in English. All participants filled a Language History Questionnaire adapted from Li, Sepanski and Zhao (2006). The experimental sessions were recorded on *.wav* files and the participants' responses were analysed in terms of reaction times and accuracy.

Three main questions were addressed in this study:

1) Will a switching cost asymmetry be found with word stimuli?
2) Will switching cost be modulated by word class?
3) Will individual levels of language proficiency predict the magnitude of switching cost?

Predictions

1) It was predicted that Italian/English bilinguals will show a switch cost asymmetry.
2) Switching cost will be modulated by whether the stimuli are singles, cognates or homographs.
3) The magnitude of switching cost will be linked to different levels of proficiency in L2.

   The results will be discussed in the light of the current debate concerning the mechanism for language selection.

9.2 Methods

Participants

Twenty healthy late Italian/English bilingual adults (9 females, mean age 34.0, SD=6.6, range 21.2-46.2) took part in this study. They were all residents in the UK at the time of testing and recruited from different professional environments. Sixteen of them had previously taken part in one of our studies. Their native language (L1) was Italian; their second language, English (L2), was acquired on average after the age of 10.0 (SD=4.6). All participants signed an informed consent and did not report any visual, speech or neurological impairment.

Materials and Procedure

All participants were tested by the same experimenter and on the same equipment (see Chapter 3) in a sound-proofed booth at the Centre for Brain and Cognitive Development, Birkbeck College, London. Five new participants filled the Language History Questionnaire adapted from Li, Sepanski and Zhao (2006) and were administered the Bilingual Verbal Ability Tests (Muñoz-Sandoval, Cummins, Alvarado, & Ruef, 1998) to assess their language proficiency in English. A description of the BVAT is provided in Chapter 4. The new participants were also administered two lexical decision task, one offline and one online to assess their degree of competence in both languages. The lexical decision tasks are described in Chapter 7.

Switching in production task

Bilingual participants were presented a total of 360 words on a computer screen, 180 in English and 180 in Italian. Words appeared one by one in sequence at the centre of the screen, with a 1.5 second interval between each other. A schematic illustration of the task is provided in Figure 9.3.

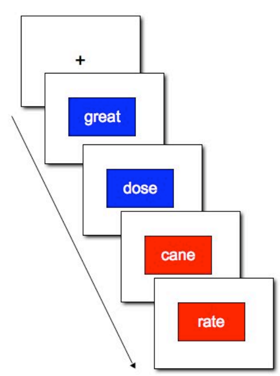


Figure 9.3 – Example of experimental run. Each run consisted of 12 words divided in 4 blocks of different size (2, 3 or 4 words) and alternated with each language.

Stimuli comprised target words with same spelling and same meaning in both languages (cognates, n=30), target words with same spelling but different meaning (homographs, n=30), and unique words in both languages (singles, n=30). An example of experimental words is shown in Table 9.1. The target words were pseudo-randomly arranged in two presentation orders in a way that they were administered both as *non-switch* and as *switch* trials. Participants were randomly assigned to one of the two orders. Target words were matched within language by their length, frequency and concreteness (see Appendix III). English words were taken from the MRC Psycholinguistic Database, (Coltheart, 1981) using the indices of word frequency (Kucera & Francis, 1967) and concreteness (Coltheart, 1981); Italian words were taken from the *Corpus e Lessico di Frequenza dell'Italiano Scritto* - CoLFIS (Laudanna, Thornton, Brown, Burani, & Marconi, 1995). Italian words had a median frequency of 221 occurrences per three million words for homographs, 101 occurrences for cognates and 94 occurrences for singles. English words had a median frequency of 44 occurrences per million words for homographs, 25 occurrences for cognates and 66 occurrences for singles. In proportion, Italian singles were less frequent than English singles and Italian homographs were more frequent than English homographs. Interlingual cognates were approximately equally frequent in both languages. The task was programmed using Matlab for Mac.

Table 9.1: An example of interlingual cognates, homographs and singles used in this study. Singles were orthographically legal in both English and Italian.

Language	**Cognates**	**Homographs**	**Singles**
Italian	*Orchestra*	*Cute* (Italian meaning=Skin)	*Canzone*
English	*Base*	*Male* (Italian meaning=Bad)	*Challenge*

Ninety English and 90 Italian filler words were also included. All fillers were unique words in both languages. A complete list of words with their frequency and concreteness is reported in Appendix III.

The task started with a filler word and each run had 3 switch trials for target words (cognates, homographs, and singles). Words were presented individually with a 1.5-second interval. Participants were required to name each word aloud as fast and accurately as possible. Words surrounded by a *blue* rectangle had to be read in Italian and words surrounded by a *red* rectangle in English. Both rectangles were sized 5.6cm x 2.8cm. Stimuli were written in white Helvetica 24, uppercase, and presented in 30 runs of 12 words, each run containing three switch trials. Trial runs were either of two, three or four words for each language, and were fully counterbalanced for unpredictable presentation in two randomly allotted orders. If x was a switch trial, there was a 64% that trial after x+1 would be a switch back into the other language. If that was not, x+2 had a chance of 91%, and x+3 = 100%. At each run completion, a fixation-cross appeared on the screen and the task was paused to allow the participants to have a short break before continuing to the next run at their own pace by pressing the space-bar on the computer keyboard. A glass of water was also provided.

Subjects were videotaped through a Sony DV camera, and their responses were recorded into *.wav* files through the Macbook built-in microphone. Reaction times were analysed using Praat phonetic software (Boersma & Weenink, 2010). An internally developed script automatically calculated the time latency between stimulus presentation and the subjects' utterance onset (Figure 9.4). All trials were subsequently checked manually and speech errors were flagged and labeled for separate analysis.

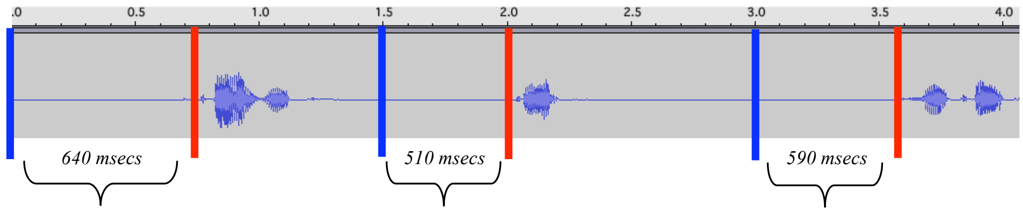


Figure 9.4 – Response time analysis. The blue lines indicate the time of stimuli presentation, and the red lines the time when the participant started to utter the words. A software script automatically calculated the latencies.

At task completion, all subjects were given the list of target words (cognates, homographs and singles) on paper and asked to indicate the ones for which they did not know the meaning, the correct pronunciation, or both. These words were subsequently excluded from the analysis.

9.3 Results

English proficiency

Participants' raw scores, ranging from level 2 (very limited) to level 5 (advanced) were computed using the *Scoring and Reporting Program for the BVAT* (Muñoz-Sandoval, Cummins, Alvarado, & Ruef, 1998). The bilinguals' biographical data and cognitive-academic level of proficiency in English (CALP) are reported in Table 9.2. The CALP is also graphically displayed in Figure 9.5

Table 9.2: Participants' biographical data (sex: female, male; age-in-years, and level of proficiency in English).

Subj	Sex	Age	CALP
1	F	41.6	4.0
2	M	31.9	4.0
3	M	38.4	3.0
4	M	29.7	3.0
5	F	40.5	4.0
6	F	35.2	4.5
7	F	21.9	2.0
8	M	38.5	3.5
9	M	21.2	3.5
10	M	32.3	3.0
11	M	36.5	4.5
12	M	35.4	4.5
13	F	39.6	2.0
14	F	25.6	4.0
15	F	35.3	3.5
16	F	26.5	3.5
17	F	38.5	4.0
18	M	46.2	5.0
19	M	35.3	4.0
20	M	30.6	2.0

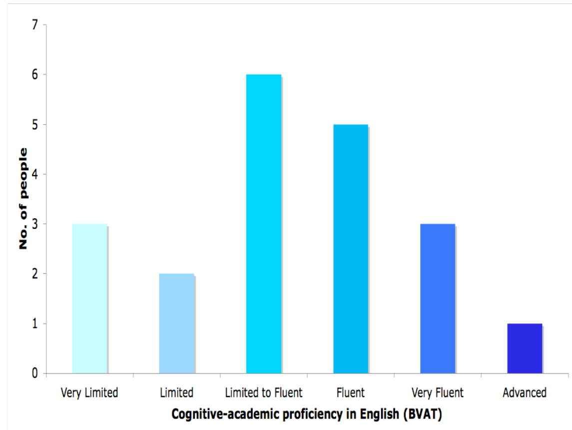


Figure 9.5: Participants' proficiency distribution.

Language competence: Lexical Decision Tasks

The Italian/English bilinguals' mean accuracy and RTs in the lexical decision tasks are shown in Table 9.3.

Table 9.3: Participants reaction times (RT) in seconds and accuracy (% CR) in the Offline and Online Lexical Decision Tasks (LDT)

Task	Stimuli	Mean	SD
Offline LDT English	% CR Words	87	11
	% CR Non-Words	85	12
Offline LDT Italian	% CR Words	98	2
	% CR Non-Words	90	11
Online LDT English	% CR Words	95	3
	% CR Non-Words	87	11
Online LDT Italian	% CR Words	98	4
	% CR Non-Words	96	3
Online LDT English	RT Words	0.60	0.07
	RT Non-Words	0.83	0.19
Online LDT Italian	RT Words	0.61	0.10
	RT Non-Words	0.80	0.15

The participants' reaction times and accuracy were analysed with a 2x2 ANOVA for language (Italian, English) and stimulus (words, non-words). For the offline task, bilinguals showed a better vocabulary knowledge in Italian with a 98% mean accuracy for words (87% in English) and 90% for non-words (85% in English), main effect of language: $F(1,19)=23.561$, $p<.001$, $\eta^2=.554$; main effect of stimulus: $F(1,19)=4.872$, $p=.040$, $\eta^2=.204$. The interaction between language and stimulus was non significant, $F(1,19)=2.441$, $p=.135$, $\eta^2=.114$, indicating that bilinguals were equally accurate with plausible non-words when performing the task in both languages. For reaction times in the online lexical decision task, bilinguals were equally fast in both languages either for words (0.01 second difference) and non-words (0.03 seconds difference), $F(1,19)=.905$, $p=.353$, $\eta^2=.045$. There was a significant main effect of stimulus, $F(1,19)=45.155$, $p<.001$, $\eta^2=.704$, indicating that non-words were processed more slowly than words in both languages, but no interaction between language and stimulus, $F(1,19)=1.702$, $p=.208$, $\eta^2=.082$, showing that bilinguals' lexical decisions were comparable in both languages for words and non-words.

For accuracy in the online lexical decision task, bilinguals were 3% more accurate for Italian words than English words and 9% for Italian non-words than English non-words, $F(1,19)=28.306$, $p<.001$, $\eta^2=.598$. A main effect of stimulus, $F(1,19)=7.381$, $p=.014$, $\eta^2=.280$ indicated that participants had a better performance with words in both languages. A reliable interaction between language and stimulus, $F(1,19)=4.955$, $p=.038$, $\eta^2=.207$, revealed that bilinguals were more accurate with plausible non-words when performing the task in Italian than in English.

Overall, these results confirmed that the bilinguals' dominant language was Italian. They were more accurate in both offline and online lexical decision tasks when they performed them in their native language. However, reaction times in the online lexical decision task were comparable for both languages, indicating that lexical access in English and Italian was more balanced for common words. These measures of language competence are used as covariates in the switching cost analysis.

Switching in production task

Start trials and filler trials were discarded from analysis. Median reaction times for each stimulus class for valid switch and non-switch trials were computed for each participant to reduce the influence of outliers. The means of the median response times and error rates by word class and type of trial are displayed in Table 9.4

Table 9.4: Mean reaction times (seconds), correct responses (%) and standard deviations (SD) for switch and non-switch trials by word class and language context.

		English context				Italian context			
		RT	SD	%CR	SD	RT	SD	%CR	SD
Cognates	*Switch*	0.82	0.09	89	9	0.82	0.08	88	11
	Non-Switch	0.71	0.09	91	7	0.64	0.09	91	7
Homographs	*Switch*	0.82	0.09	91	10	0.87	0.13	83	19
	Non-Switch	0.71	0.09	90	12	0.72	0.10	88	10
Singles	*Switch*	0.76	0.08	99	3	0.71	0.06	98	5
	Non-Switch	0.67	0.08	97	5	0.62	0.09	99	3

A 3x2x2 repeated measures ANOVA for word type (cognates, homographs, and singles), language (Italian, English), and trial type (switch, non-switch) was carried out. Overall, participants showed slightly faster responses in Italian than in English (Italian: 0.73 seconds; English: 0.75 seconds) but made fewer errors in naming English words than Italian words (Italian 91%, English 93%). However, omnibus ANOVA revealed that neither difference was reliable, response times: $F(1,19)=2.421$, p=.136, η^2=.011; accuracy: $F(1,19)$=1.299, p=.269, η^2=.064. A significant reaction time cost was observed for responses on switch trials compared to non-switch trials, $F(1,19)$=110.70, p<.001, η^2=.853. On average, participants took 0.68 seconds to respond on a non-switch trial and 0.80 seconds to respond on a switch trial, a mean switch cost of 0.12 seconds. Analysis of accuracy showed a non-significant cost of 2% to switch languages, $F(1,19)$=1.329, p=.253, η^2=.068.

As shown in Figures 9.6 and 9.7 for latencies, and Figures 9.8 and 9.9 for accuracy, participants had different response times and error rates depending on the type of words, $F(2,38)$=65.307, p<.001, η^2=.775; accuracy: $F(2,38)$=22.118, p<.001, η^2=.538. Participants were faster and more accurate in naming singles (mean reaction time: 0.69 seconds; mean accuracy: 98%) than cognates (0.74; 90%) and homographs (0.78; 88%). The differences survived a Bonferroni correction for multiple post-hoc comparisons for reaction times. For accuracy, the difference between cognates and homographs was not reliable.

The interaction between trial and word type was significant for response time, $F(2,38)$=5.683, p=.007, η^2=.230. On average, participants showed a smaller switching cost for singles (0.09 seconds) than cognates (0.14 seconds) and homographs (0.11 seconds). Bonferroni-corrected *t*-tests showed that switch cost was reliable between cognates and singles, $t(19)$=4.318, corrected, p=.001, but not between cognates and homographs and between homographs and singles (p>.05). For accuracy, the interaction between trial and word type was not significant, $F(2,38)$=1.145, p=.329, η^2=.057. The interaction between word type and language for response time and accuracy was also significant, indicating that cognates, homographs and singles were processed differently in the two languages, response times: $F(2,38)$=12.41, p<.001, η^2=.395; accuracy: $F(2,38)$=3.752, p=.033, η^2=.165. For reaction times, participants were 0.05 seconds faster in naming singles in Italian than English, a difference that survived a Bonferroni-corrected comparison. For cognates, they were 0.03 seconds faster in Italian, but the difference did not survive Bonferroni. Participants did not show any difference in RT for homographs. For accuracy, they were 7% and 9% more accurate in naming singles and homographs in Italian respectively, but 4% more accurate when naming cognates in the English context. None of these differences survived a Bonferroni comparison. These results indicated that the effect was modulated by language dominance, that is, bilinguals were faster in naming single words in their native language, Italian. However, the effect disappeared with cognates and homographs.

It is worth noticing that although accuracy results are not always reliable, the direction of differences was consistent with RT results and did not suggest any speed/accuracy tradeoffs.

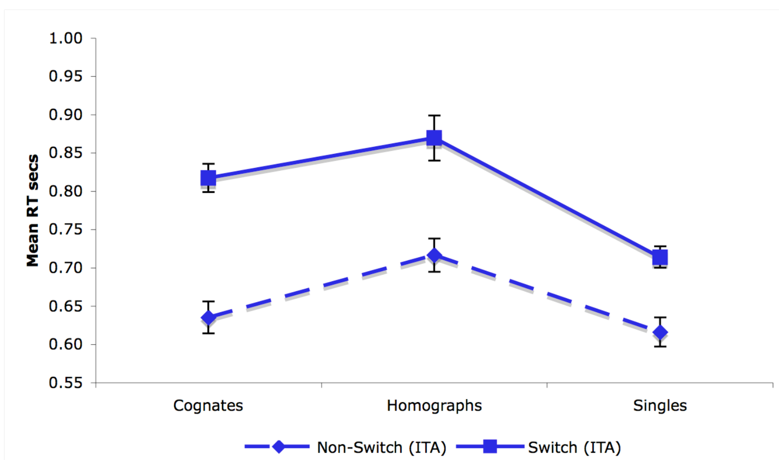


Figure 9.6: Participants' response time (seconds) and standard errors for switch and non-switch trials when naming cognates, homographs and singles in Italian.

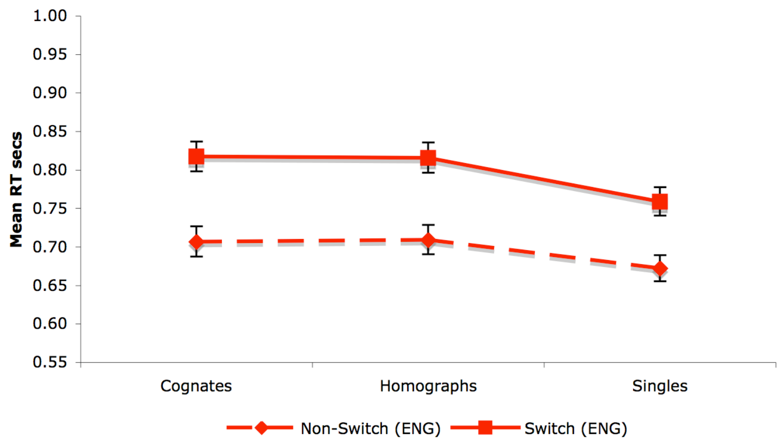


Figure 9.7: Participants' response time (seconds) and standard errors for switch and non-switch trials when naming cognates, homographs and singles in English.

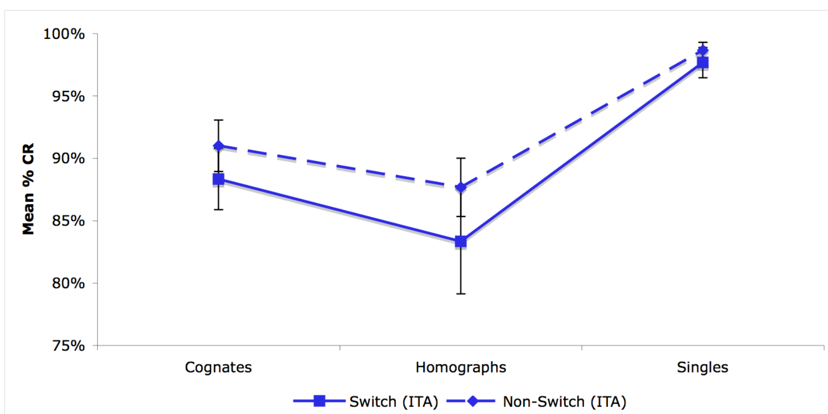


Figure 9.8: Participants' accuracy (percent correct responses) and standard errors for switch and non-switch trials when naming cognates, homographs and singles in Italian.

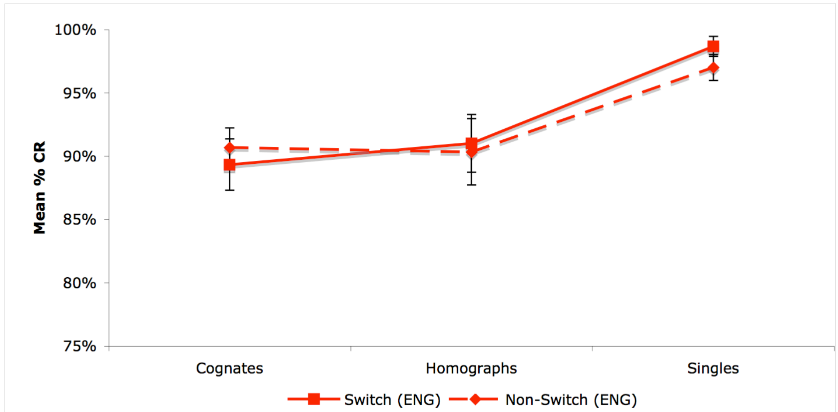


Figure 9.9: Participants' accuracy (percent correct responses) and standard errors for switch and non-switch trials when naming cognates, homographs and singles in English.

Turning to the factors that modulated switch costs, an omnibus analysis of variance failed to detect a three way interaction between language, word type, and trial, $F(2,38)=1.467$, $p=.243$, $\eta^2=.072$. As shown in Figure 9.10, this was due to a larger variability in switching cost for homographs. A further investigation including only cognates and singles as the independent variable for word type, revealed a significant interaction between word type and language, $F(1,19)= 6.794$, $p=.017$, $\eta^2=.263$. The interaction survived a Bonferroni correction. This result indicated an asymmetric switching cost for cognates, that is, participants' took more time to switch into their native language, Italian, than their second language, English, when naming words sharing the same orthography and meaning in the two languages. There was no asymmetry, however, for singles. The same analysis repeated for error rates did not yield a reliable result, $F(2,38)=.347$, $p=.709$, $\eta^2=.018$, indicating that participants' switching cost was comparable between the two languages in terms of accuracy, as shown in Figure 9.11.

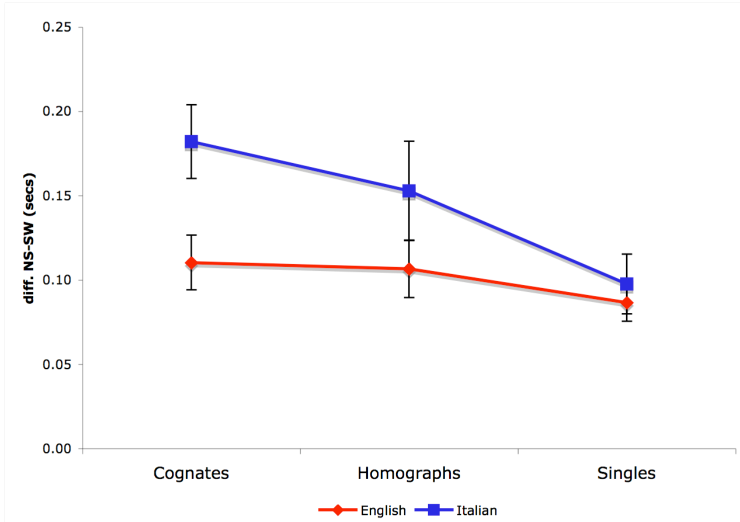


Figure 9.10: Participants' switching cost asymmetry between English and Italian for cognates and homographs. Switch cost is defined as the difference between switch and non-switch trials, here expressed in seconds.

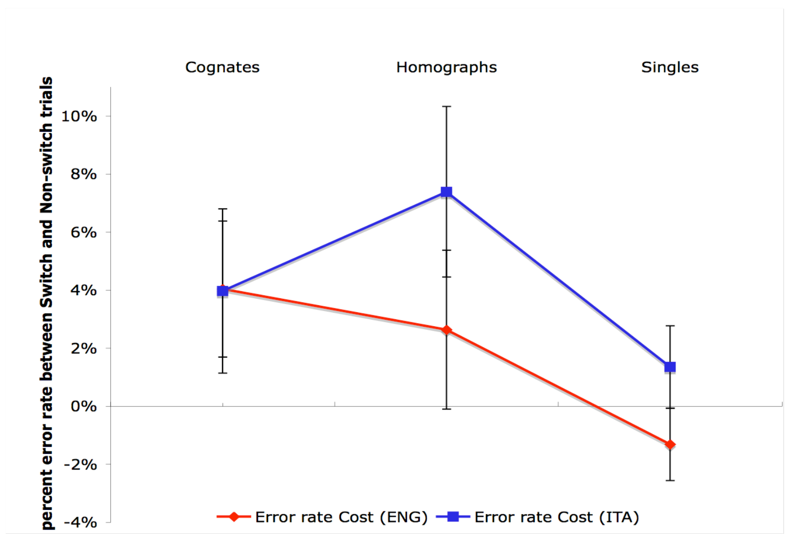


Figure 9.11: Participants' switching cost asymmetry between English and Italian for cognates and homographs. Switch cost here is defined as the difference between switch and non-switch trials in terms of percent of errors. A result in the negative territory, means that there was an advantage rather than a cost between a non-switch and a switch trial.

Correlation between measures of language competence and switching cost

The switching cost asymmetry was correlated with the individual measures of language competence from the standardised tests (BVAT – Muñoz-Sandoval, Cummins, Alvarado, & Ruef, 1998) and the lexical decision tasks. The difference between L1 and L2 in terms of accuracy and in terms of reaction times was computed for the offline and the online lexical decision tasks respectively. Pearson's correlation coefficients and p-values are reported in Table 9.5.

Table 9.5: Relation of each subject's measures of language competence with switching cost.

Correlation	Pearson's Corr. Coeff.	p-value
BVAT and Switching cost	**-.417**	**.067**
Offline LDT (% accuracy difference between L1 and L2) and Switching Cost	.263	.262
Online LDT (RT difference between L1 and L2) and Switching Cost	.221	.349

As shown in Figure 9.12, levels of proficiency were negatively associated to cost asymmetry. Regression analysis checked for outliers (Cook & Dennis, 1977), showed that the correlation approached significance level, $F(1,18)=3.799$, $p=.067$. The association with the other offline and online measures of language competence was not significant. In sum, the trend indicated that participants with limited L2 proficiency exhibited greater cost for switching into L1 than high proficient bilinguals.

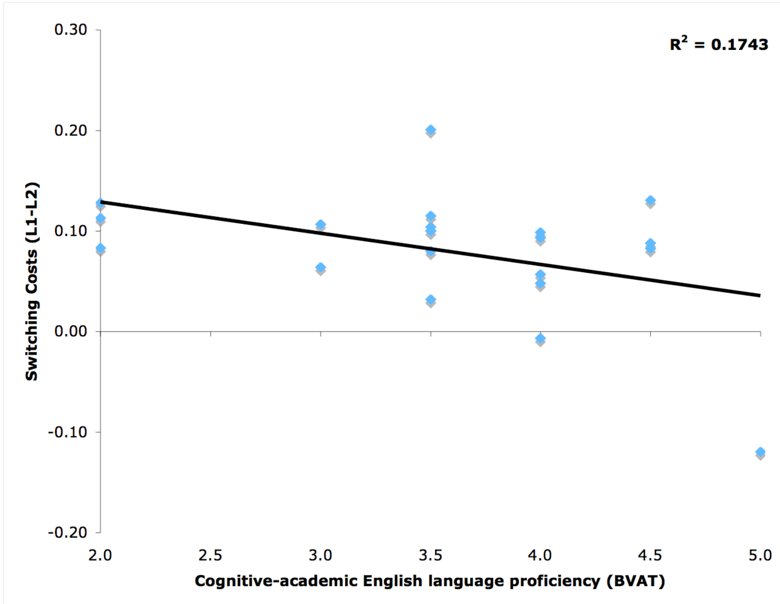


Figure 9.12: Relation of each subject's L2 proficiency with switching cost asymmetry.

Errors

Overall, participants made 4% errors. As we have seen, these tended to occur more often on switch trials but not reliably so. The majority of these errors, 74%, were approximately equally distributed between two main categories: (1) *Lexical*, in which participants named the word using the non-target language; (2) *Sublexical*, in which participants started to articulate the word using the non-target language and switched to the target language before completing the word. This occurred in two ways: (1) starting with the wrong phonology, then pausing when mistake was detected, and finally producing the word in the target language starting from scratch, and; (2) starting with the wrong phonology then correcting to the right articulation without interruption (an example of this type of errors is displayed in Figure 9.13). The remaining errors were those in which participants either mispronounced the word, particularly when it was an English word, or failed to name the word at all.

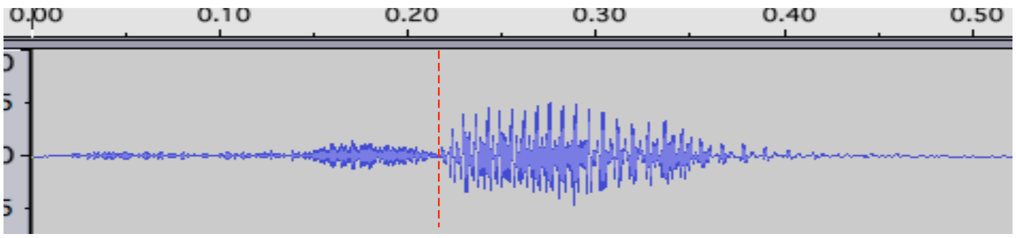


Figure 9.13: An example of a *Sublexical* mixed language error. Here the subject is required to name the *cognate* word "*Scene*" in English [sēn]. However the participant started with the articulation in Italian [ʃʃɛne] and continued after the red dashed line with the correct articulation in English. The word produced is a mix of Italian ʃʃ and English *ēn* which form a "novel" word *[ʃʃ ēn]*.

As shown in Table 9.6, errors were subsequently divided into switch and non-switch errors, either in English and Italian. The errors were overwhelmingly driven by the existence of a word form in both languages: fifty percent of them were made with interlingual homographs, 42% with cognates and only 8% with singles.

With both languages combined, lexical errors occurred more frequently in switch (59/99) than non-switch (40/99) trials. Pearson's chi-square indicated that this trend was approaching significance level, $\chi^2(1)= 3.65$, $p=.056$. However, there was no significant association with sublexical errors in both switch (51/90) and non-switch (49/90) trials. For English, there was no reliable association for lexical and sublexical errors in both switch and non-switch trials. For Italian, Pearson's chi-square showed that lexical errors occurred more in switch trials (39/63) than non-switch trials (24/63). The association approached significance level, $\chi^2(1)= 3.57$, $p=.058$.

However, as in the English case, sublexical errors when performing the task in Italian occurred with comparable frequency in both switch and non-switch trials.

Table 9.6: Type of errors by language and trial type.

	English		**Italian**	
	Non-Switch	*Switch*	*Non-Switch*	*Switch*
Lexical	16	20	24	39
Sublexical	23	20	26	31
Others	36	29	16	18

9.4 Discussion

This study aimed to investigate the switching cost in bilingual language production by using a cue to manipulate language of output. For this purpose, a group of late Italian/English bilingual adults living in the UK at the time of testing, took part in a mixed-block switching paradigm, extending Meuter and Allport's (1999). Italian and English cognate, homograph and single word stimuli were used in this study instead of digits. Participants were required to name each word in the language cued by a colour surrounding the word, i.e., red for English and blue for Italian. The bilinguals' degree of proficiency in L2 was assessed with a standardised test, the Bilingual Verbal Ability Tests (BVAT - Muñoz-Sandoval, Cummins, Alvarado, & Ruef, 1998). The test indicated that the bilingual participants' level of cognitive-academic proficiency in English ranged from low to high levels of proficiency.

As predicted, results from the word-naming task showed that the magnitude of switching cost was larger for L1 than for L2. Late bilingual speakers took more time to switch into their native language, Italian, than their second language, English. Thus, they exhibited an asymmetrical switching cost replicating previous observations (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999).

Analysis of switching cost by word class, revealed that latencies were greater for *cognates* but not for *homographs* and for *singles*. Therefore, words sharing the same form and meaning in both languages caused more interference indicating that both L1 and L2 were active in parallel during speech planning. It is worth noticing, that despite interlingual homographs were more frequent in Italian than English (see Appendix IV), latencies were greater with Italian homographs than English homographs, although a Bonferroni-corrected *t*-test indicated that the difference was not significant. However, this pattern would suggest that greater interference is not just due to the difference in frequency of interlingual homographs (Dijkstra et al., 1998). A possible explanation could be that while naming in L1, L2 has been boosted in readiness for use, hence exaggerating interference. Overall, these results provided further support for a non-selective bilingual lexical access: activations flows from the conceptual system to the two languages.

In line with the prediction of the ICM (Green, 1986, 1998), the individual degrees of proficiency modulated the magnitude of switching cost. A negative trend approaching significance level indicated that low proficient bilinguals had a greater cost when switching into their dominant language, Italian. The cost decreased when proficiency levels increased (Costa & Santesteban, 2004; Meuter & Allport, 1999).

Analysis of errors revealed a trend for more lexical errors (i.e., the language of utterance is the non-target language) when there was a switch, and particularly when the switch was into L1. Lexical access is related to control mechanism and these errors may indicate a stronger inhibition of L1 when performing the task in the weaker L2. As far as sublexical errors are concerned (i.e., mixed-language utterances), they occurred randomly across trials and languages. Errors of this type have been previously reported in the literature of code-switching (e.g., de Bot, 1992;

Poulisse & Bongaerts, 1994). Their occurrence is attributed to a single mechanism, the articulator, which is involved in the selection of phonemes. It is therefore hypotesised that L1 and L2 phonological representations are stored in a single network and tagged for language, as for lexical items (Poulisse, 1999; Poulisse & Bongaerts, 1994). However, Grosjean and Miller (1994) did not find any specific phonological intrusion of one language when switching into the other using a more naturalistic experimental setting. Participants asked to read English and French passages with controlled language switches, did not show any phonetic carryover effect when switching between languages. It may be speculated that sublexical errors are the result of less naturalistic experimental designs where the tight pace of the task is the principal cause for slip-of-the-tongue effects, as it may occur to a monolingual speaker.

9.5 Conclusions

In summary, the findings in this study corroborated the view for a non-selective bilingual lexical access. In line with the ICM, both languages are active in parallel and compete for selection. Moreover, the notion for reactive inhibition was also supported in this study; the more dominant L1 required more inhibition than the weaker L2, resulting in a switch cost asymmetry, which was negatively associated to the individual levels of L2 proficiency.

In the next chapter I will use the magnetic resonance imaging (MRI) technique to address the question whether control abilities required of bilingual are reflected in structural differences in the brain. Novel approach of this study is that I will be using individual differences on experimental measures of control (i.e., on the cross-linguistic diotic listening and the Simon Task) to explore localised grey matter density change associated with control of interference.

Chapter 10

Study 6: Control of interference in the bilingual brain

10.1 Introduction

A crucial question in bilingual research is how bilingual speakers manage the competition from two languages without showing any obvious dysfluency. As we saw in previous chapters, there is growing evidence that both languages may be active in parallel (e.g., Dijkstra, Van Jaarsveld & Brinke, 1998; Van Hell & Dijkstra 2002; Von Studnitz & Green, 2002) and that the non-target language may be suppressed through inhibitory processes beyond the language system (Green, 1986, 1998). Interestingly, some studies have shown that bilinguals outperform monolinguals on a range of executive function tasks, such as the Simon task (e.g., Bialystok, Martin & Viswanathan, 2005; Martin-Rhee & Bialystok, 2008), and the attention network task (ANT - Costa, Hernandez & Sebastián-Gallés, 2008). A possible explanation of this link between these phenomena is that the constant "overtraining" in controlling which of the two languages is used may in turn enhance general-domain cognitive control abilities, especially those requiring inhibition of irrelevant information and monitoring (e.g., Bialystok, 2010; Bialystok, Craik, Klein & Viswanathan, 2004; Costa et al., 2008). To further test this hypothesis, I investigated how the ability to control interference was related to long-term plasticity in brain structure. Are there brain regions where grey matter (GM) and white matter (WM) are greater in those who are good at controlling interference? Are the same brain regions associated with the control of verbal and nonverbal interference? To our knowledge, these questions have not previously been addressed with structural neuroimaging. In particular, the second point is crucial because, as we saw in the previous chapters, the psycholinguistic literature does not offer an exhaustive explanation. Thus, neural evidence may provide new critical information, which in turn may be relevant to the cognitive level theory.

Our a priori predictions were based on previous functional imaging studies. In particular, two studies by Rodriguez-Fornells and colleagues (Rodriguez-Fornells, Rotte, Heinze, Noesselt, & Muente, 2002; Rodriguez-Fornells, vander Lugt, Rotte, Britti, Heinze, & Muente, 2005) explored the neural correlates for bilingual language selection. In the first study (Rodriguez-Fornells et al., 2002) the authors addressed the question of how bilinguals control interference from the non-target language by using event-related potentials (ERPs) and fMRI. They presented Spanish/Catalan bilingual adults and Spanish monolinguals with Spanish words, Catalan words and pseudowords with instructions to press a button when a word was in Spanish and refrain from pressing the button for Catalan words and pseudowords. The inclusion of Catalan words was expected to introduce lexical interference in the bilingual participants but not in the monolingual participants. The results showed that bilinguals had greater activation than monolinguals in the left ventral pars opercularis in the posterior inferior frontal cortex (MNI[3]: *x* -60, *y* 8, *z* 8) and in the left anterior pars triangularis which is in a more anterior part of the ventral inferior frontal gyrus (*x* -44, *y* 28, *z* 8). The authors concluded that these areas might be implicated in the control of lexical interference from the non-target language (i.e., Catalan). In a second fMRI study, Rodriguez-Fornells et al. (2005) investigated the effect of phonological rather than lexical interference in a task that required German/Spanish bilinguals and monolingual German participants to respond if a visually presented picture started with a consonant and withhold their response if it started with a vowel (go/no-go trials, see Colomé, 2001). On half of the trials there was a mismatch between the correct response in German and Spanish (e.g., the word for '*strawberry*' is '*erdbeere*' in German which starts with a vowel and '*fresa*' in Spanish which does not start with

[3] MNI= Montreal Neurological Institute. The MNI defined a new standard brain by using a large series of MRI scans on normal controls.

a vowel). These mismatches were expected to introduce interference in the bilinguals but not the monolinguals. Indeed, during the no-go mismatch trials, the bilinguals showed more activation than the monolinguals in a left middle frontal region (MNI: *x* -40, *y* 36, *z* 32) and the supplementary motor cortex (SMA). Plausibly, the left inferior and middle frontal activation observed for bilinguals relative to monolinguals might reflect domain-general control functions that are used in language selection and the control of interference (Abutalebi & Green, 2007). However, the Rodriguez-Fornells studies (2002, 2005) were not designed to distinguish activation related to '*increased interference*' from activation related to increased demands on the mechanism that control interference and thus '*decrease interference'*. In fMRI it is very difficult to distinguish activation that is related to the mechanisms that control interference from processing related to interference itself, as they both co-occur. In this study I focused specifically on the mechanism that controls interference to decrease interference. To dissociate brain regions associated with the control of interference from the effect of interference per se, I correlated grey matter density in structural MRI images acquired when bilingual participants were resting in the scanner with the ability to control interference measured outside the scanner. Thus, as the images were collected in the absence of interference, structural imaging offered an ideal opportunity to dissociate the mechanisms that control interference from interference per se. In addition, I compared how the observed effects depended on the ability to control verbal interference with the ability to control non-verbal interference.

Our participants were a group of late Italian/English bilingual adults. Our analysis involved both an unbiased whole-brain search for areas where grey matter correlated with the ability to control interference, and a region of interest (ROI) that focused on the left frontal regions associated with language control by Rodriguez-

Fornells and colleagues' work (2002, 2005). Specifically, to contrast control similarity between verbal and nonverbal interference, I looked for brain regions positively correlated with more efficient processing of stimuli under conditions of interference across two different tasks already used in this research project: (1) a verbal sentence interpretation task; and, (2) the non-verbal Simon task. As described in Chapter 7, in the sentence interpretation task participants had to identify the agent in a series of sentences varying in structured complexity (i.e., canonical Subject-Verb-Object, and non-canonical Object-Verb-Subject, Object-Subject-Verb) in the presence or in the absence of language interference presented simultaneously in both ears (diotic listening). The results in study 3 showed that bilinguals outperformed monolingual peers: when performing the same condition, bilinguals focused their attention more efficiently to the target sentence and screened out language interference, especially when the task was harder, that is, while processing non-canonical sentences (passives and object clefts) and under conditions of native language interference.

As described in Chapters 5 and 7, the Simon Task is an executive function non-verbal task in which participants must resolve the stimulus-response conflict given by congruent and incongruent trials. On congruent trials, the colour stimulus matches the side of the button (e.g., red square requiring left button response appearing on the left side of the screen). On incongruent trials, the colour stimulus does not match the side of the button (e.g. red square requiring left button response appearing on the right side of the screen), leading to slower reaction times. Although bilinguals are generally reported to perform the Simon task more easily than monolinguals by being faster in reaction times for both congruent and incongruent trials (Bialystok et al., 2004; Martin-Rhee & Bialystok, 2008), this research project did not provide evidence for a bilingual advantage in this task. However, the results indicated that the Simon Task was a sensitive measure of cognitive control: all participants were equally affected by the interference caused by incongruent trials.

For each of these tasks, I computed a score that measured the individual's efficiency in controlling interference and used those as regressors in the voxel-based morphometry analysis (VBM). VBM is a fully automated technique allowing identification of regional differences in the amount of GM and WM enabling an objective analysis of the whole brain between subjects. In this study, the main advantage of using a VBM analysis of structural MRI images rather than fMRI is that we can focus on processing abilities (i.e., the efficiency with which interference can be controlled) as opposed to processing per se. In contrast, fMRI measures the effect of processing per se. Although processing may change with ability, complicated fMRI experimental designs are required to tease apart "processing" from "ability" and different types of processing (e.g., activation related to increased interference versus activation related to increased control of interference). Structural imaging and VBM therefore allows our question to be addressed in a simpler and more direct fashion. The techniques I used are fully automated (Ashburner & Friston, 2000) and well established for investigating language function (see Richardson & Price, 2009, for a review). For example, Mechelli and colleagues (Mechelli, Crinion, Noppeney, O'Doherty, Ashburner, Frackoviak, & Price, 2005) found an effect of language learning on grey matter density in the posterior supramarginal gyri in healthy Italian/English bilinguals at different levels of L2 proficiency and age of acquisition (AoA). The effect of language learning on brain reorganisation has been further observed in studies exploring speech perception (Golestani et al., 2002, 2007) where learning rate of novel sounds was positively associated with a bilateral WM density in the anterior pariatel-occipital sulcus (Golestani et al., 2002) and the Helsch's gyrus (Golestani et al., 2002). Moreover, structural MRI revealed that greater WM density in the left insula/prefrontral cortex and the inferior parietal lobes is associated with a more accurate pronunciation in the bilingual speech production (Golestani & Pallier, 2007; Grogan et al., 2009). Although the VBM technique presents some limitations (Mechelli et al., 2005; Richardson & Price, 2009), the convergence between structural and functional results may help researchers find novel insights and establish the relationship among specific brain structures, language skills and functional activation. For example, Richardson, Thomas, Filippi, Harth and Price (2009) used functional and structural imaging in the same study investigating vocabulary knowledge across the lifespan. The authors demonstrated a close link between functional activation in the left posterior temporal regions and grey matter density correlated with vocabulary in monolingual participants ranging from 7 to 73 years of age. They also found that grey matter in the posterior supramarginal gyrus, a region associated with bilingual proficiency in Mechelli et al.'s (2005) study, correlated with vocabulary knowledge only in the teenage years. This finding may suggest that this region is particularly engaged when formal education occurs.

10.2 Methods

Participants

Twenty-seven Italian/English bilingual adults (15 females, mean age 32.9, SD=7.1, range 21.3-41.4) took part in this study. They were all resident in the UK and recruited from different professional environments. Twenty-five of them had already taken part in one of our studies. All new participants completed a language history questionnaire adapted from Li, Sepanski and Zhao (2001) and performed two lexical decision tasks, one online and one offline, in both known langauges. They all learnt a second language later in life, with the exception of one subject who was raised in England from an Italian family. They were all right-handed apart from one who reported to be left-handed.

Behavioural measures

1. The sentence interpretation task

A full description of this task is included in Chapter 7. For the purpose of this study, given that all participants were native speakers of Italian, only the most demanding condition, that is, comprehending English non-canonical sentences in the presence of Italian interference, was used as a regressor. The proportion of correct responses in the interference condition was divided by the responses in the baseline condition (i.e., without language interference) to obtain a task ability score. The score may be on a negative scale because performance on non-interference (baseline) tasks was generally better than that of interference conditions. Therefore, lower negative scores represent a better ability to manage interference. All scores are displayed in Table 10.2. Reaction times were also collected and analysed. However, as target sentences and interference sentences were not time-locked, they could not be directly related to underlying interference. Thus, only accuracy wast used in this analysis.

2. Simon Task

This task was identical to the one administered in study 1 and 3, and it is described in Chapter 5. Reaction times and error rates were computed to obtain a composite task efficiency score. In this case, an efficiency score falling in the negative territory means a better performance with congruent trials. Thus, the more positive the score, the more efficient the participant was on the most demanding incongruent trials. The efficiency scores are also displayed in Table 10.2.

3. Lexical Decision Tasks

Bilinguals' language competence in both languages was measured with two lexical decision tasks, one offline with low-frequency words to test word knowledge, and one online with high/medium-frequency words to test lexical access. Plausible non-words obeying the orthography and phonotactics were created for each language.

Both lexical decision tasks are described in Chapter 7.

4. Standardised tests

Participants were administered two standardised tests: (1) the Bilingual Verbal Ability Tests (BVAT - Muñoz-Sandoval, Cummins, Alvarado, & Ruef, 1998) was used to assess their level of proficiency in English; (2) The Matrices task from the BAS-II (Elliot, Smith, & McCulloch, 1997) measured non-verbal reasoning and was used as a stand-in for performance IQ. Both tests are described in Chapter 4.

Brain imaging procedure

For the brain scan, all participants were tested individually at the Institute of Neurology, Wellcome Trust Centre for Neuroimaging, London. On their arrival, they filled a consent form in which they reported their health condition, past operations, and a possible presence of metal implants in their body. Before entering the scanner, they were told to rest keeping their head as still as possible for the whole scanning session, which would last approximately 13 minutes. At session completion, the participants were shown computer images of the brain, explained the various anatomical areas and debriefed about the main objectives of the study.

Structural imaging

1. Structural image acquisition

Focal grey matter density was estimated on the basis of T1-weighted anatomical whole brain images acquired using a Siemens Sonata 1.5T MRI scanner (Siemens

Medical Systems, Erlangen, Germany). A T1-weighted Modified Driven Equilibrium Fourier Transform (MDEFT) sequence (Deichmann, Schwarzbauer & Turner, 2004) was used to acquire 176 sagittal partitions with an image matrix of 256x224 yielding a final resolution of $1mm^3$ (TR/TE/TI = 12.24 ms/3.56 ms/530 ms).

2. Structural image analysis

Scans were analysed using SPM 8 (Wellcome Department of Imaging Neuroscience, http://www.fil.ion.ucl.ac.uk/spm). Structural images were processed using the Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra (DARTEL) toolbox available in SPM 8 (Ashburner, 2007, 2009). DARTEL uses a more sophisticated registration model than previous approaches implemented in the SPM software (Ashburner, 2009). Structural images were first segmented in native space into grey and white matter. A template brain was then created in DARTEL using default parameter settings. This process iteratively matches selected images to a template generated by their own mean. The resulting flow fields containing deformation information generated by this process were then used to spatially normalise grey matter images to MNI space. The concentration of grey matter in these images was preserved, generating unmodulated grey matter images. The values at each voxel are typically referred to as representing grey matter density (Mechelli et al., 2005). The normalised images were then smoothed using an isotropic kernel of 8mm at full-width half-maximum (FWHM).

3. Statistical analyses of structural data.

Task ability and efficiency scores were computed for both linguistic and non-linguistic measures. A multiple regression analysis was carried out in SPM 8 to find the main effect of efficient processing of stimuli under conditions of verbal and non-verbal interference within our 27 participants, whilst factoring out variance associated with general intellectual ability. In order to model linear effects of age, age-in-years was also included. Thus, 4 regressors were used in the analysis: (1) ability scores in the sentence interpretation task with the highest cognitive load condition, i.e., English non-canonical sentences (target) and Italian interference (distractor); (2) task efficiency in the Simon Task; (3) Matrices, general non-verbal intellectual ability scores; and, (4) age in years.

Statistical threshold

In order to identify the most salient effects on regional grey matter density, our statistical threshold for the multiple regression analysis was set to $p < 0.05$ for height after family-wise correction for multiple comparisons across the whole brain. For our regions of interest (ROIs) statistical correction was at $p<0.05$ FWE corrected within a 12 mm search radius of the peak voxel. The ROIs are listed in Table 10.1.

Table 10.1: Regions of interest (ROIs) in this study.

Anatomical Localisation	Coordinates			Study
	x	*y*	*z*	
Left fusiform gyrus	-36	-84	-8	Rodriguez-Fornells et al. (2005)
Left middle frontal cortex	-40	36	32	Rodriguez-Fornells et al. (2005)
Left ventral pars opercularis	-60	8	8	Rodriguez-Fornells et al. (2002)
Left pars triangularis	-44	28	8	Rodriguez-Fornells et al. (2002)

10.3 Results

Behavioural results

Language competence measured with two lexical decision tasks, one offline and one online, revealed that bilinguals were generally more competent in their native language, Italian. Results from the standardised Bilingual Verbal Ability Tests (Muñoz-Sandoval, Cummins, Alvarado & Ruef, 1998), showed that the participants' degree of English proficiency ranged from *very limited* to *advanced*. Statistical analyses, tables and a graphic representation of proficiency distribution are reported in Appendix VI.

For the sentence interpretation of non-canonical English sentences in the presence of Italian (native) language interference, participants were 9% (SD=8.0) less accurate in the interference condition than in the baseline condition with no interference, $F(1,26)=31.678$, $p<.001$, $\eta^2=.549$. For the Simon Task, analysis of reaction times and accuracy revealed that participants were 0.50 second slower (SD=0.5) and 5% (SD=5.3) less accurate on incongruent than congruent trials, $F(1,26)=58.377$, $p<.001$, $\eta^2=.692$; $F(1,26)=6.733$, $p<.015$, $\eta^2=.206$, respectively. Individual raw scores and the computation of task ability in the sentence interpretation task and task efficiency in the Simon task are reported in Table 10.2.

Table 10.2: Individual raw scores for all 27 participants in the sentence interpretation task and the Simon task. In the sentence interpretation task, the proportion of correct responses with and without language interference was computed to produce a task ability score. In the Simon task, reaction times (seconds) and proportion of correct responses were computed to produce a task efficiency score. Both ability and efficiency scores were used as regressors in the VBM analysis.

Subjs.	SENTENCE INTERPRETATION TASK			SIMON TASK				
	No Interference (prop.correct resp.)	Italian Interference (prop.correct resp.)	TASK ABILITY	RT Congruent Trials (seconds)	RT Incongruent Trials (seconds)	CR Congruent Trials (prop.CR)	CR Incongruent Trials (prop.CR)	TASK EFFICIENCY
1	0.98	1.00	***0.25***	0.34	0.37	0.86	1.00	***0.77***
2	1.00	0.92	***-1.00***	0.52	0.57	0.93	0.79	***-1.28***
3	0.96	0.92	***-0.50***	0.32	0.43	0.93	0.64	***-4.37***
4	0.96	0.88	***-1.00***	0.35	0.38	0.93	0.79	***-1.92***
5	0.88	0.88	***0.00***	0.36	0.46	1.00	0.93	***-2.43***
6	0.96	0.92	***-0.50***	0.43	0.49	1.00	0.93	***-1.34***
7	0.96	0.88	***-1.00***	0.44	0.46	1.00	1.00	***-0.22***
8	0.85	0.72	***-1.63***	0.38	0.40	1.00	0.93	***-0.95***
9	1.00	0.96	***-0.50***	0.35	0.39	0.93	1.00	***-0.09***
10	0.96	0.76	***-2.51***	0.34	0.40	1.00	1.00	***-1.42***
11	1.00	0.92	***-1.00***	0.37	0.42	1.00	1.00	***-0.99***
12	0.67	0.56	***-1.38***	0.31	0.38	1.00	0.71	***-3.98***
13	0.96	0.96	***0.00***	0.47	0.47	1.00	1.00	***0.02***
14	0.92	0.72	***-2.51***	0.37	0.38	1.00	0.93	***-0.84***
15	0.94	0.80	***-1.76***	0.36	0.38	1.00	0.93	***-1.00***
16	0.83	0.76	***-0.88***	0.40	0.44	1.00	1.00	***-0.81***
17	0.83	0.56	***-3.39***	0.43	0.47	1.00	0.93	***-1.13***
18	0.98	0.84	***-1.76***	0.41	0.46	1.00	0.93	***-1.32***
19	0.96	0.84	***-1.51***	0.40	0.47	0.79	0.93	***0.10***
20	0.96	1.00	***0.50***	0.41	0.45	1.00	0.93	***-1.16***
21	1.00	0.76	***-3.01***	0.42	0.44	1.00	0.93	***-0.74***
22	0.92	0.80	***-1.51***	0.46	0.51	1.00	1.00	***-0.59***
23	1.00	0.88	***-1.51***	0.41	0.47	0.93	0.93	***-0.96***
24	0.98	0.96	***-0.25***	0.37	0.38	0.93	1.00	***0.57***
25	1.00	0.92	***-1.00***	0.35	0.49	1.00	0.93	***-2.86***
26	1.00	1.00	***0.00***	0.37	0.46	1.00	0.86	***-2.69***
27	0.79	0.80	***0.13***	0.32	0.36	0.93	0.86	***-1.71***
Mean	0.94	0.85	-1.08	0.39	0.44	0.97	0.92	-1.23
SD	0.08	0.12	1.00	0.05	0.05	0.05	0.09	1.22

Voxel-based morphometry results

Whole brain analysis

To begin, a whole-brain search for the main effect of efficient control of interference (over the verbal sentence interpretation task and the nonverbal Simon task) revealed a positive correlation between the efficiency with which interference was controlled and grey matter density in the posterior lobe of the right cerebellum, p=0.024 (FWE corrected).

The location of the effect can be seen in Figure 10.1. The significance of the effect (cluster size and z-values) are listed in Table 10.3; and a scattergram showing the individual data points is provided in Figures 10.2a and 10.2b.

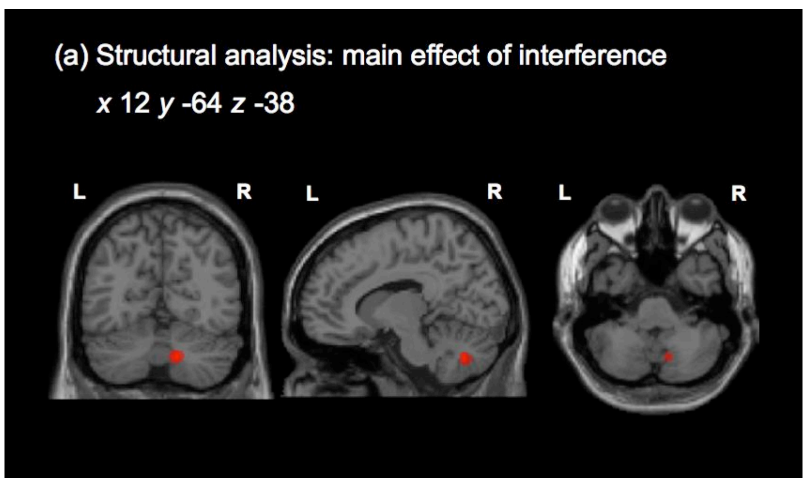
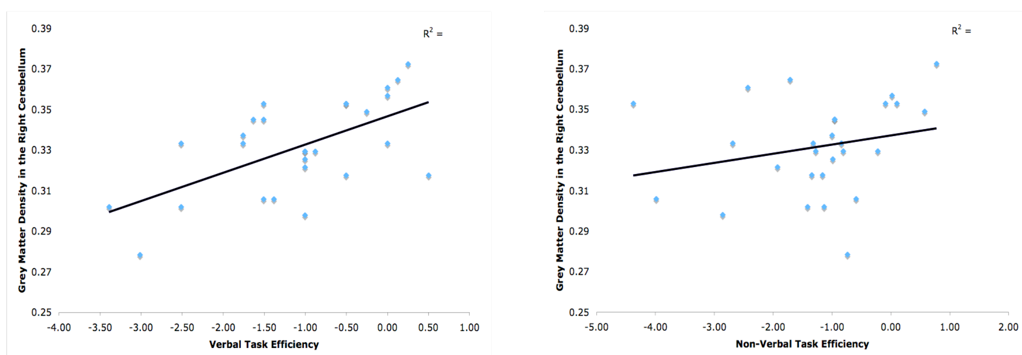


Figure 10.1: Structural analysis results: the highlighted region (red) shows the area where grey matter density is higher in those bilinguals with more efficient performance in the context of interference.

Table 10.3: Effects of efficiency in stimulus processing ***1***: main effect of both efficiency measures (for controlling verbal and non-verbal interference). ***2***: effect of controlling verbal interference after the effect of controlling nonverbal interference has been partialled out.

		Anatomical Localisation in the Cerebellum	**Coordinates** *x*	*y*	*z*	**Cluster size**	**z-value**
1	Verbal and non-verbal	Right posterior lobe - Uvula	12	-64	-38	238	5.3[4]
2	Verbal only	Right posterior lobe – Uvula	12	-64	-38	161	5.2[5]

[4,5] Significant at p<0.05 FWE corrected for height



(a) **(b)**

Figure 10.2: a) Scattergram of individual ability scores in the sentence interpretation task and **b)** efficiency in the Simon Task (x-axis), and grey matter density in the right cerebellum (y-axis).

Regression analysis showed that best performance in the sentence interpretation task was a significant predictor for increased grey matter density in the right cerebellum (R^2=0.36, p=.001). In contrast, task efficiency in the Simon task did not reliably predict increased grey matter density in the same region (R^2=0.05, p=.111). Non-parametric correlations yielded to the same results.

Region of interest analysis

Voxel-based morphometry did not reveal grey matter density differences in the left inferior and middle frontal regions associated with the control of interference by Rodriguez-Fornells and colleagues (2002, 2005). The null effects observed in our regions of interest require further investigation, probably with fMRI, to determine whether activation in these areas during interference conditions reflects processing related to interference per se or processing related to the control of interference.

10.4 Discussion

This structural imaging study of the ability to control verbal and non-verbal interference revealed an unexpected result: the efficiency with which interference can be controlled correlates with grey matter density in a very ventral region of the right cerebellum. This finding raises the question of what the function of this region is. To provide supporting evidence from previous studies that this region of the cerebellum is functionally related to the control of interference, I conducted a literature review of structural and functional MRI studies of language processing. This led to a re-analysis of fMRI data collected in recent studies of bilingual language processing carried out at the Functional Imaging Lab (FIL – Wellcome Trust Centre for Neuroimaging). The literature search did not identify any studies that had activated the same right cerebellar region. The most likely explanation for the absence of effects so low in the cerebellum is that whole-brain fMRI data acquisition occurs slice by slice. To improve sensitivity, language researchers typically cut out the inferior part of the cerebellum despite a well-established knowledge that the cerebellum is involved in cognitive processing (see Stoodley & Schmahman, 2009, for a review). In contrast, in PET data, the lowest part of these regions is always included. Thus, in order to look for a functional correspondence of the VBM findings and in an attempt to draw meaningful conclusions, the PET data from a study of bilingualism reported in Crinion et al. (2006) were re-analysed.

In the Crinion et al. study (2006), 25 highly proficient German/English adult bilinguals who learned their second language from the age of 11 made semantic decisions on written words in L1 or L2 that were either primed with a word in the L1 (i.e., prime-target: L1-L1 or L1-L2) or L2 (i.e., L2-L1 or L2-L2). The aim of the study was to compare activation reductions when the primes were semantically related to the targets versus semantically unrelated to the targets; and to test how the effect of semantic priming depended on whether the prime was in the same or different language to the target. The results of these analyses have already been reported in Crinion et al. (2006) and demonstrated semantic priming both within and across languages for related pairs. The re-analysis excluded all the semantic primes and focused on activation differences produced by blocks of trials where targets were preceded by an unrelated prime in L1 versus an unrelated prime in L2. The expectation was that the semantics associated with the prime would interfere with the semantics related to the target; and this interference effect would be greater when the prime was presented in L1 (German) than in L2 (English). The re-analysis of the data therefore compared activation from L1 unrelated primes relative to L2 unrelated primes. This identified a region at a stastistical threshold of $p<0.001$, the right cerebellum in the uvula (x 22, y -62, z -44 and x 20, y -64, z -38; 216 voxels). As displayed in Figure 10.3, this region is just lateral to the area associated with the control of language interference in the VBM study.

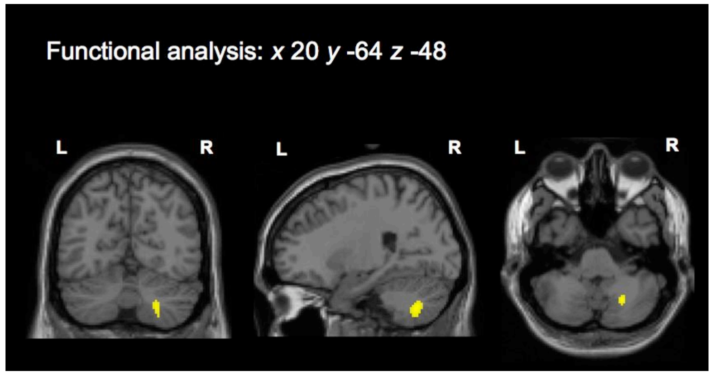


Figure 10.3: Cerebellar functional activation observed for German-English bilinguals performing semantic decisions on written words in the context of semantically unrelated written word primes that were presented in L1 (more interference) compared to L2 (less interference). This result was obtained from a re-analysis of the PET data reported in Crinion et al. (2006) and has not previously been reported.

In summary, the re-analysis of the PET data from Crinion et al. (2006) showed that the right cerebellar region where a correlation in grey matter density and the ability to control verbal interference was observed is more activated in the context of interference from a native language (L1) than a less well known language (L2). Without the structural imaging results, it would not be possible to say whether this increased activation for L1 versus L2 interference was a consequence of interference per se or the mechanisms that control interference. Combined with our structural imaging findings, it can be shown that fMRI activation related to increased verbal interference was identified in the right cerebellar region that the structural imaging study associated with the ability to control verbal interference. However, as the two areas are not exactly the same, further analyses will be carried out to provide dual evidence to support the association of the uvula in the right cerebellum with the control of verbal interference.

10.5 Conclusions

The main aim of this study was to investigate whether brain regions associated with the control of verbal interference were the same or different to these associated with nonverbal control. Therefore, it was addressed the issue of whether any benefits of bilngualism extended beyond the language system itself. Structural imaging was used to focus on the participants' ability to control interference rather than processing related to interference per se. We were able to distinguish between these two by focusing on the correlation between the participants' brain morphology and their individual ability scores in the sentence interpretation task and the Simon task. A whole brain analysis revealed a robust positive correlation between grey matter density in a region of the posterior lobe in the right cerebellum and task efficiency scores in the presence of native language interference. The correlation between grey matter and the ability to control nonverbal interference in the Simon task was not reliable. Therefore this study did not provide evidence that the same mechanisms were involved in controlling verbal and nonverbal interference. However, a weak trend ($p=.111$) suggested that this conclusion should be treated with some caution and more research is required.

Due to a lack of data reporting cerebellar activation within the fMRI literature, data were re-analysed from Crinion et al.'s (2006) PET study. Data re-analysis showed an increased activation in a region somewhat lateral and ventral to the one observed in the structural study when late bilinguals performed a semantic-judgment task in the context of interference from L1 relative to interference from L2. With functional and structural results combined, it may be inferred that the region of the right posterior lobe of the cerebellum is involved in cognitive processing, in particular in managing linguistic interference deriving from a native language in late bilingual speakers.

Cerebellum involvement in language and the control of verbal interference

Although the cerebellum has traditionally been seen as limited to the control of coordinated movement, there is growing evidence that this subcortical structure plays a role in cognition, behaviour and psychiatric illness (e.g., Fabbro, 2000; Justus & Ivry, 2001 Rapaport, van Reekum, Mayberg, 2000; Silveri, Misciagna, 2000; Stoodley & Schmahman, 2009; Tomasi, Chang, Caparelli & Ernst, 2007). Stoodley and Schmahman (2009) have recently conducted a meta-analysis of neuroimaging studies reporting activation in the cerebellum in the attempt to draw a topographic organization of its higher-order function. The authors selected 281 studies which were split in 7 categories: (1) motor; (2) language; (3) somatosensory; (4) working memory; (5) executive function; (6) spatial processing; and, (7) limbic/emotional processing. Meta-analysis revealed that the different regions of the cerebellum process information from different domains. Sensorimotor information is processed in the anterior lobe, cognitive information is processed in the posterior lobe, and emotional information is processed in the posterior vermis. Meta-analysis also revealed that language was strongly lateralised in the right lobe of the cerebellum, reflecting contralateral projections with the cerebral cortex.

Both functional imaging and lesions studies have highlighted the importance of the right cerebellum for language processing. For example, Jansen et al., (2005) used functional imaging in healthy left and right handed individuals and found that the degree of left lateralized activation in the cerebral hemisphere was positively correlated with the degree of right lateralized activation in the cerebellum. Lesion studies have also shown that the effect of right cerebellar damage on language function mirrors that seen after left frontal lobe damage. For example, Schweizer et al. (2010) found that during a phonemic fluency task, patients with right cerebellar lesions produced significantly fewer words compared to patients with left cerebellar lesions or healthy controls. This deficit was not explained in terms of motor speech impairment but to a reduction in switches between task strategies. Switching between strategies maximizes phonemic fluency. For example, participants might start by generating words that are synonymous (e.g., slender, slim) and then generate words that begin with the same letters (e.g., small, smart). The strategic control of these strategies is impaired in patients with damage to the right cerebellum (Schweizer et al., 2010) and left prefrontal cortex (Alexander, Stuss, Picton, Shallice, & Gillingham, 2007).

Although I did not find direct evidence to support the prediction that the left prefrontal cortex was involved in the control of verbal interference, I did find evidence for the role of a right cerebellum region. The association of the right cerebellum with control mechanisms is consistent with the well established view that the cerebellum is involved in the modulation rather than generation of cognitive and motor functions (Schmahmann,1996; Murdoch, 2010).

In summary, structural imaging and VBM revealed a positive correlation between grey matter density and efficiency in controlling verbal interference in a region of the right posterior lobe of the cerebellum. This result can be open to two possible interpretations: 1) greater grey matter density can be the result of a skill acquisition process, or, 2) increased grey matter density was preexistent, and therefore facilitated the acquisition of this particular skill. A causal inference could only be established with a longitudinal study in which the learning effects on the participants' brain structure can be monitored across a given period of time.

Overall, the results of the present study, if correct, would expand our knowledge on the cerebellar contribution to cognitive processing and should encourage neuroscientists to further explore the cerebellum and its interconnections with the cerebral cortex.

Chapter 11

General discussion and conclusions

"Niuna impresa, pur minima che sia, può avere cominciamento o fine senza queste tre cose: cioè senza sapere, senza potere, senza con amore volere"

Anonimo fiorentino del 1300

"No enterprise can either start or finish without these three things: knowledge, ability, and, most of all, without love"

Anonymous Florentine of 1300

11.1 Introduction

"*Language acquisition is a journey that begins in the fluid world of the womb and continues throughout childhood, adolescence and beyond*" (Karmiloff-Smith, 2001, p. 1). This quotation provides an immediate dimension of the importance of language in our life. The experience of learning more than one language adds new routes to this journey. At the beginning, these routes might be tortuous, almost inaccessible. Learning a second language early in life might seem "effortless". However, it requires a formidable combination of cognitive abilities. Learning a second language later in life might seem "effortful". However, an adult learner relies on different mechanisms such as a well-developed strategy to memorise information and linguistic rules that in turn allows him/her to learn a second language at a faster rate than a child (Hudson Kam & Newport, 2005). Both enterprises could not be possible if our brain were not able to accommodate the input coming from experience by reorganising its structure through neuronal plasticity. The main aim of this thesis was to examine part of this journey and investigate how second language acquisition affects human cognition both early and later in life. This question was addressed by comparing early bilingual children to monolingual children, and late bilingual adults to monolingual adults. This thesis represents one of the first attempts to directly compare linguistic and non-linguistic abilities by using both behavioural and neuroimaging techniques. It was innovative because it used cross-sectional developmental trajectories to explore differences in linguistic and cognitive control development between bilingual and monolingual children (study 1), extended to bilingual sentence comprehension (study 3), and explored for the first time how the ability to control interference was related to long-term plasticity in the bilingual brain (study 6). Table 11.1 summarises all the findings for each study.

Table 11.1: Summary of all studies: participants, tasks and findings.

Study	Participants	Task	Findings
1 & 2	54 Early bilingual children age 4 to 7 45 age-matched English mononlingual children	BPVS: Standard measure of English receptive vocabulary	Bilingual children generally showed typical L2 acquisition but trajectory was not linear
		Simon Task: Executive Function	No difference between the groups
		Raven's Col. Matr.: General IQ	No difference between the groups
		Probabilistic Learning	No difference between the groups
		Correlation Analyses	SES (parental education) positively correlated with linguistic achievements but not EF in both groups One parent L2 native speaker predicted best vocabulary acquisition in bilingual children
3	20 late bilingual adults 20 English monolinguals 18 Italian monolinguals	Sentence Interpr.: language compr. with and without interference	Bilinguals were more accurate than Italian monolinguals with non-canonical sentences and L1 interference. No difference with canonical sentences. No difference between bilinguals and English monolinguals with both sentence classes.
		Simon Task: Executive Function	No difference between the groups
		Online LDT: lexical access	Bilinguals were slower and less accurate in English, but had same performance of Italian monolinguals when the task was in Italian
		Offline LDT: vocab.knowledge	Bilinguals were less accurate in English. No difference with Italian monolinguals.
		Correlation Analyses	L2 proficiency was positively correlated with best inhibition of interference in L1. No association between L2 proficiency and EF.
4	18 late bilingual adults 18 English monolinguals	Diotic listening: Inhibition/Monitoring	Bilinguals were faster but equally accurate with both switch/non-switch conflicting and non-conflicting trials
		Ping: Auditory-motor baseline	No difference between the groups
5	20 late bilingual adults	Lang. switching in prod.	Larger switching cost when switch into L1. Switching cost modulated by word class suggesting that both languages are active in parallel before production occurs.
		Correlation Analysis	Switching cost trend negatively correlated with L2 proficiency (reactive inhibition)
6	27 late bilingual adults	- MRI and VBM	Control of L1 linguistic interference positively associated with regional variations in grey matter density of the right cerebellum.

In the following paragraphs, I consider the main experimental findings in relation to the theories introduced earlier in chapters 1 and 2. Finally, I seek to identify the strength and weakness in each study and the directions for future research.

11.2 How do the studies answer the three leading questions and what do they add to the existing literature?

Question 1: Does the bilingual experience enhance children's and adults' cognitive functioning?

Early bilingualism: cognitive transfer effects

Study 1 investigated a possible bilingual advantage in cognitive control and differences in linguistic abilities between early bilingual children and English monolingual peers aged 4 to 7 years old. This study did not provide evidence for a bilingual advantage in cognitive control. When early bilingual children were compared to monolingual peers using a measure of executive functioning, the Simon Task, they exhibited equal performance. Additionally, the results of study 2 showed that bilingual children were not different from monolinguals when learning underlying regularities in a probabilistic association task. These findings are in contrast with previously reported evidence showing a bilingual advantage in cognitive control using the Simon task (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008) and a cued learning task (Kovács & Mehler, 2009). Rather, Study 2 provided a hint that bilingual children might be slower than monolingual peers at learning a probabilistic association in the presence of conflicting information, a result in demand of further attention in future studies.

With both bilingual and monolingual children combined, a partial measure of SES, i.e., the parental level of education, did not predict best performance in the Simon task. This is also in contrast with previous research in which a reliable correlation between executive function abilities and parental SES was found, regardless of the linguistic status (Morton & Harper, 2007).

Linguistic skills

Bilingual children are often reported as disadvantaged in the L2 vocabulary acquisition when compared to monolingual speakers of that language at all observed ages (e.g., Bialystok & Feng, in press). However, a trajectory analysis in Chapter 5, showed an overall typical development for bilinguals in English acquisition when compared with monolingual peers, although the trend was not linear: 4-year-old and 6-year-old bilinguals showed a disadvantage over monolinguals, but bilingual children of about 5 years of age did not. This pattern could be due to sampling issues but further research is needed. If real, the result would predict that the bilingual disadvantage in vocabulary would depend on the age at which the comparison with monolinguals is made.

Perhaps, the most interesting findings were the strong correlations between parental education and linguistic achievements for both bilingual and monolinguals ($p=.001$), and between vocabulary knowledge and the regular use of the second language within the family for bilingual children ($p=.005$). Where at least one parent was a native speaker of English, bilingual children had a greater English vocabulary than children whose parents were both non-native speakers of English. This result may provide an important indication for educators who could target children from families in which both parents are non-native speakers of English and in need of more linguistic intervention.

In summary, there was no evidence in both study 1 and 2 that early exposure to more than one language would in turn result to a cognitive control advantage over monolingual speakers.

Late bilingualism: control in language comprehension

Study 3 and 4 explored attentional processes with auditory stimuli. In particular, study 3 used a diotic listening sentence comprehension paradigm where two messages were presented simultaneously to both ears, whereas study 4 used another diotic listening paradigm with simple voice instructions and switching between the perceptual properties of the speech input. Both studies provided evidence for an enhanced attentional system in Italian adults who learned English later in life and moved to London at a certain point in their life.

In particular, Study 3 provided novel evidence for a bilingual advantage in verbal control beyond the syllable level (Soveri et al., 2010) and word-level (e.g., Bialystok et al., 2008), to the level of sentence interpretation. In the key contrast, Italian/English bilingual adults compared with Italian monolingual peers living in Italy, exhibited a better comprehension of Italian non-canonical sentences in the presence of Italian language interference. Surprisingly, despite they acquired English later in life and had different degrees of proficiency, they showed equal performance with a group of English monolinguals, a result that is discussed later on this chapter. I attributed this finding to a more efficient attentional processing when the task was more difficult (i.e., high-load cognitive demand). In fact, there was no difference between the groups when the task was easier, i.e., with canonical sentences either in the presence or in the absence of Italian interference. This result is in line with Lavie's work (1995, 2005) on selective attention in which it is postulated that a high cognitive-control load processing increases distractor interference. This result was supported by the findings of study 4, which explored attentional processing during switching simple instructions in the presence of target-conflicting and target-non-conflicting language interference. In particular I was interested in measuring if bilinguals were able to inhibit the irrelevant information early or later in the comprehension process, that is, whether any bilingual advantage operated at a perceptual level or higher in the language system. The results of study 4 indicated that bilinguals were faster than monolinguals but equally accurate when switching between trials regardless of whether they were conflicting or non-conflicting trials. On the other hand, both groups were slower with conflicting trials, suggesting that inhibition may occur later in the comprehension process. Additionally, the absence of interaction between conflicting and non-conflicting trials between the two groups suggested that bilinguals were no better than monolinguals at inhibiting irrelevant information. The results of Study 4 confirmed that the attentional advantage may not be confined only to inhibitory processing; in line with novel findings (e.g., Costa et al., 2009; Bialystok, 2010), bilinguals showed an advantage also in monitoring the target information. Additionally, in accord with Study 3, bilinguals performed better than monolinguals when the cognitive demand of the task was higher, that is, bilinguals were faster than monolinguals at inhibiting interference when the task presented an increased level of difficulty (i.e., the input source was the male's voice). Study 3 provided compelling evidence that level of proficiency in the second language is a reliable predictor of best performance even when the task was carried out in the native language, suggesting that this might be a side effect of bilingualism per se. Thus, it could be inferred that better inhibitors are better at learning a second language. However, there was no evidence for a bilingual cognitive control advantage in a non-verbal executive function task, the Simon Task. As for early bilingual children, late bilingual adults' performance was comparable with monolinguals. Thus, in contrast with the studies that used the Simon task (e.g., Bialystok et al., 2004), the attentional advantages observed in this research project were confined to the language system.

Question 2: How do bilinguals manage to control their two languages?

Study 5 aimed to investigate switching costs within a group of late Italian/Bilingual adults who had already participated in the language comprehension studies. For this purpose I expanded Meuter and Allport's (1999) paradigm using a word-naming switching task instead of digits. In line with previous findings (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999), a switching cost asymmetry was observed: participants were slower when switching back into their native language, Italian. However, switching cost was modulated by cognate words, that is, words sharing the same spelling and the same meaning in both English and Italian. There was no switching cost for words that did not share any morphological or semantic information (singles). Our results supported two main hypotheses: (1) both languages are active in parallel before one is selected for production (e.g., Dijkstra, Van Jaarsveld & Brinke, 1998; Van Hell & Dijkstra 2002; Von Studnitz & Green, 2002); and, (2) switching cost asymmetry could be the result of reactive inhibition: the prepotent influence of a dominant L1 (Italian in our case) may require stronger inhibition, which in turn may result in a higher cognitive effort for its reactivation, as predicted by the ICM model (Green, 1986, 1998).

The concept of reactive inhibition was further supported when the participants' performance was regressed against individual levels of L2 proficiency. A negative linear trend ($p=.067$) indicated that low proficient bilinguals had a greater cost when switching into their L1. However, the cost decreased as long as L2 proficiency increased (Costa & Santesteban, 2004; Meuter & Allport, 1999).

In summary, the findings of study 5 corroborated the view for a non-selective bilingual lexical access in production as observed in previous studies of visual word recognition. Our findings were also in line with the ICM, which postulates that both language are active in parallel and compete for selection and advances the notion for reactive inhibition which proportionally modulates cost asymmetry when bilingual switch between languages in production.

Question 3: Will brain structures change as a function of increased ability to control both languages?

The last study of this research project used magnetic resonance imaging (MRI) and voxel-based morphometry (VBM) to explore brain regions where grey matter density (GM) could be greater in those who are more efficient at controlling interference. Additionally, I also aimed to investigate if the same brain regions were associated with the control of verbal and nonverbal interference.

For this purpose, I computed the individual ability scores to control linguistic interference in the sentence interpretation task used in study 3, and the efficiency scores in resolving the motor-visual conflict in the Simon task, which was used in study 1 and 3. Both scores served as regressors in the VBM analysis as regressors.

Whole-brain analysis revealed a reliable positive correlation between grey matter density in a region of the posterior lobe in the right cerebellum and task efficiency scores in the presence of interference. However, the correlation was reliable only for the sentence interpretation task in the condition of high cognitive load, that is, when the task was performed in L2 and interference was in L1. As this structural relationship is a novel finding, the functional data for Crinion et al. (2006) PET study were re-analysed in search of corroborating data on the processing role of this region. The re-analysis found that the nearby region in the cerebellum is activated in the context of L1 interference. Finally, multiple regression analysis revealed that the Simon task was not a reliable predictor for increased grey matter density in this region.

In sum, the results of both studies combined revealed that control of interference from the dominant language (L1) may be structurally and functionally associated to a region in the right cerebellum. However, as the increased grey matter density observed in the structural study is not exactly the same as the region of increased activation in the functional study, further analyses need to be carried out.

Overall, this novel finding corroborated previous findings on the involvement of the cerebellum in cognitive processing (Fabbro, 2000; Justus & Ivry, 2001 Rapaport, van Reekum, Mayberg, 2000; Silveri, Misciagna, 2000; Tomasi, Chang, Caparelli & Ernst, 2007), and also confirmed that language processing is lateralised in the right posterior lobe of the cerebellum (Stoodley & Schmahman, 2009). However, there was no evidence that experience controlling verbal interference generalised to an advantage controlling nonverbal interference.

11.4 How can discrepancies between the current and previous studies can be accounted for?

Non-verbal abilities

One of the main criticism questioning previous findings on the bilingual executive control advantage regards the lack of experimental control. Bilingual and monolingual children are often compared in mono-cultural settings (e.g., French/English

Canadian); in particular social class and culture are considered crucial factors that modulate executive functioning (e.g., Hedden, Ketay, Aron, Markus, & Gabrieli, 2008). The bilingual children who participated in this research project were selected strategically; they came from 11 different Countries in 4 different Continents. They spoke 11 different languages, including European, Indo-European, and Afroasiatic languages. The results of my studies indicated that when culture is properly controlled, the beneficial effect of bilingualism on executive function may be harder to detect and larger samples might be required. As discussed in Chapter 2, the Simon task offered the possibility to test both children and adults. Post hoc power analysis ruled out the possibility that null results were due to a small sample, questioning the sensitivity of this paradigm. Intriguing theories have been recently built on the finding based on the Simon task (e.g., Bialystok et al., 2004), therefore our results, together with other published papers (e.g., Morton & Harper, 2007), posit an important base to continue this line of investigation with other executive function paradigms. The bilingual advantage in cognitive functioning is not under dispute here; there is growing evidence showing that the bilingual experience may provide cognitive benefits beyond the language system. This advantage was found perhaps with more sensitive tasks, such as the ANT task (Costa et al., 2007), and testing larger samples (i.e., N=100). However, even in this case the effect of culture and social class has not clearly been identified: can Spanish monolingual speakers living in the Isle of Tenerife be comparable to Spanish/Catalan bilinguals living in Barcelona, without taking into account clear socio-economic and cultural differences?

Verbal abilities

If a bilingual advantage in non-verbal tasks strongly supports the idea that language control in bilinguals uses a more general control system that resolves conflict, it is also important to establish that bilingualism enhances conflict control when the task is a linguistic one. Do bilinguals also show an advantage when performing a higher-level speech processing task? The results in Study 3 provided novel and intriguing findings on the bilingual ability to comprehend syntactically complex sentences in the presence of linguistic interference and extended evidence for a bilingual advantage in verbal control beyond the syllable level (Soveri et al., 2010); word-level (e.g., Bialystok et al., 2008) to the level of sentence interpretation. The effects observed here were obtained with late bilinguals, immersed in a second-language environment and using and listening to both languages throughout the day. It remains to be seen whether such effects generalize to other bilingual speakers. Most crucially, this work, along with others examining issues to do with language control, needs to be complemented with longitudinal research in order to examine within the individual the relationship between proficiency in a second language and effective cognitive control.

The bilingual brain

As discussed in Chapter 2, Abutalebi and Green (2007) proposed a control network for language switching and selection, which includes cortical and subcortical region in the human cortex. The network derives from findings of functional and elettrophysiological studies (e.g., Crinion et al., 2006; Rodriguez-Fornells et al., 2002, 2005). However, to my knowledge, no previous study has reported a link between the cerebellum and the control of verbal interference, a finding that characterised Study 6. I suggested that this is because the identified area is in a relatively inferior part of the cerebellum that is typically excluded from fMRI studies using serial multi-slice acquisition in order to maximize sensitivity in other regions. This novel finding strongly suggests that future fMRI studies of language control should include the cerebellum.

11.5 Strengths and weaknesses of this research project

Experiments with children

One of the main points of strength in study 1 and 2 is related to the bilingual sample that was not confined to a specific linguistic or cultural population. This is crucial in order to avoid any possible confound associated with these factors. I found that nurseries and primary schools in London are an ideal environment to conduct bilingual research; the school head and teachers were eager to collaborate with us due to the significant impact that this research could have on educational and social programmes and to an overall better understanding of bilingualism in general. With their valuable collaboration, a large number of children could be tested in a reasonably short period of time.

However, the main weakness of this study is the lack of parental involvement; despite the school issuing three formal requests within the period of testing, many parents did not return a completed questionnaire. Additionally, at the school's request, it was not possible to acquire sensitive data, such as family income. A more detailed knowledge about the children's environment may have helped with a more thourough interpretation of the results.

With regard to the methods used in both studies, there are at least two considerations to make: (1) the probabilistic learning task, despite its child-friendly design, showed limited promise for explaining cognitive differences between bilingual and monolingual children due to its poor developmental sensitivity; (2) my main concern that children could get easily bored with long tasks, led me to limit the number of trials, in particular for the probabilistic learning task. However, this concern proved ungrounded. All children, regardless of their language, culture or religion, were enthusiastic to play with my computer, push buttons, name pictures and resolve problems. They were actually sad when returned to their teachers after the experiment was completed.

Experiments with adults

The results of study 3 provided robust evidence of a bilingual advantage in selecting attention to a target sentence and ignoring interference in their native language. However, these results were limited to a specific linguistic and cultural group (Italians). When bilinguals were compared with English monolinguals, results did not show any difference in comprehension of canonical and non-canonical sentences in the presence or absence of interference. This result was somewhat surprising as bilinguals showed a reliable difference in L2 competence when compared with native speakers of English. It was therefore speculated that an enhanced ability to direct attention to L2 target sentences might compensate the lack of competence in English. However, this is just a conjecture that needs further investigation. Overall, this study needs to be replicated using other languages and cultural groups to rule out any possible confound that may have affected the results. On the other hand, the results of study 4 provided robust evidence that the bilinguals' advantage is still present when different cultural groups are compared (Italian/English bilinguals vs. English monolinguals).

Voxel-based morphometry

The VBM technique presents some limitations mainly due to individual differences in brain morphology that might cause potential confounds in the interpretation of the results (Mechelli et al., 2005). However, VBM applied in our study had some important advantanges. As explained in Chapter 10, in fMRI methodology it is difficult to dissociate the activation that is related to the mechanisms that control interference from processing related to interference itself, as both co-occur. With structural imaging it was possible to focus on the mechanisms that control interference because the images were collected when there was no interference (and the images are not sensitive to activation). Therefore structural imaging offered an ideal opportunity to dissociate the mechanisms that control interference from interference per se. The possible convergence of the results with functional findings (Crinion et al., 2006) gave further support to the novel result: this is important, since the region was identified on a post-hoc whole-brain analysis.

However, quoting a well-known motto in experimental research, "*correlation is not causation*". VBM cannot tell us if increase grey matter density is either the result of learning or a preexistent condition to facilitate learning. It is therefore my intention to investigate this further with a longitudinal study.

11.6 Conclusions and further directions

The results presented in this thesis shed new light on bilingual cognitive processing and control. The combined use of behavioural and neuroimaging techniques, as well as standardised measures of linguistic and non-linguistic abilities, provided new evidence that the attentional system might be enhanced in those who acquired a second language. However, in contrast with the current literature, I did not observe a bilingual cognitive control advantage beyond the linguistic system, neither behaviourally nor by using neuroimaging techniques. As Morton and Harper (2009) put it *"…the findings* [no difference between bilinguals and monolinguals in the Simon task] *should not be dismissed simply because they do not fit with conventional* *wisdom. We believe they should give us pause"* (p. 503).

During the 3-year course of this research project, more questions were raised. However, due to time constraints it was not possible to further extend my investigation. In particular, it is my aim, with collaborators, to conduct futher analyses on the structural data of the MRI study (Chapter 10). Another area in need of further studies is that of children development. During discussions with the head teacher in the primary school where I conducted my first studies with the children, it emerged that recent internal reports showed that bilingual children, even those with low SES families (free meals), outperformed English monolingual peers in linguistic and non-linguistic subjects by the time they finish primary school. This result appeared to be exceptional as many of those children had very little knowledge of English when they started school at 5-year old, or nursery at 3-year old. This developmental trajectory should be investigated longitudinally using a wider range of linguistic and non-linguistic tests and neuroimaging techniques as well as SES measures, to understand what are the cognitive dynamics that allow bilingual children to outperform monolinguals even when they start from a disadvantaged position. The findings obtained by the combination of educational and neuroscientific techniques (educational neuroscience) could be highly relevant to promote better learning.

As far as late bilingualism is concerned, the study of control of interference in the adult population should be replicated with other cultural/linguistic groups. If the bilingual advantage on the attentional system observed in this thesis is real, the study could be extended to at least two lines of research exploring inhibitory processing, one educational and one clinical. On the educational side, can an enhanced ability in inhibiting irrelevant information be a predictor of successful second language learning? If so, new techniques could be created to strengthen inhibition mechanisms that will in turn facilitate the acquisition and the proficient use of a second language. On the clinical side, if becoming proficient in a second language enhances the ability to inhibit linguistic interference, bilingual patients suffering from brain damage should show a differential pattern of recovery when compared with monolinguals suffering similar brain damage. This hypothesis could be explored in collaboration with clinical units and language therapists. Additionally, the contribution of cerebellar areas and how they interconnect with the cognitive control system in the cerebrum should be further explored in both clinical and non-clinical bilingual and monolingual populations.

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Appendix I

List of stimuli used in the sentence interpretation task. English sentences were adapted from Leech et al. (2007) study and translated into Italian. Sentences were split into two categories, canonical (actives and subject clefts) and non-canonical (passives and object clefts). Please, see Chapter 7 for the design.

Actives *(Canonical S-V-O)*	
English	**Italian**
The Parrot is biting The Bull	Il Pappagallo Morde il Toro
The Goat is chasing The Snake	La Capra Insegue il Serpente
The Cat is eating The Eagle	Il Gatto Mangia l' Aquila
The Fox is grabbing The Seal	La Volpe Afferra la Foca
The Horse is bumping The Bull	Il Cavallo Colpisce il Lupo
The Whale is hurting The Dog	La Balena Ferisce il Cane
The Cats are kicking The Seals	I Gatti Calciano le Foche
The Foxes are pulling The Monkeys	Le Volpi Tirano le Scimmie
The Dogs are pushing The Horses	I Cani Spingono i Cavalli
The Goats are scratching The Snakes	Le Capre Graffiano i Lupi
The Pigs are scaring The Eagles	I Maiali Spaventano le Aquile
The Whales are hitting The Frogs	Le Balene Picchiano le Rane
The Bull is biting The Cats	Il Toro Morde i Gatti
The Seal is chasing The Pigs	La Foca Insegue i Maiali
The Snake is eating The Goats	Il Serpente Mangia le Capre
The Eagle is grabbing The Foxes	L' Aquila Afferra le Volpi
The Wolf is bumping The Parrots	Il Lupo Colpisce i Pappagalli
The Cow is hurting The Whales	La Mucca Ferisce le Balene
The Bulls are kicking The Goat	I Tori Calciano la Capra
The Seals are pulling The Whale	Le Foche Tirano la Balena
The Snakes are pushing The Pig	I Serpenti Spingono il Maiale
The Frogs are scratching The Parrot	Le Rane Graffiano il Pappagallo
The Horses are scaring The Monkey	I Pappagalli Spaventano la Scimmia
The Eagles are hitting The Frog	Le Aquile Picchiano la Rana

Subject Clefts *(Canonical S-V-O)*	
English	**Italian**
It's the Pig that is Kicking the Whale	E' il Maiale che Calcia la Balena
It's the Monkey that is Pulling the Fox	E' la Scimmia che Tira la Volpe
It's the Cat that is Pushing the Pig	E' il Gatto che Spinge il Maiale
It's the Fox that is Scratching the Cat	E' la Volpe che Graffia il Gatto
It's the Horse that is Scaring the Monkey	E' il Cavallo che Spaventa la Scimmia
It's the Goat that is Hitting the Frog	E' la Capra che Picchia la Rana
It's the Bulls that are Kicking the Seals	Sono i Tori che Calciano le Foche
It's the Eagles that are Pulling the Monkeys	Sono le Aquile che Tirano le Scimmie
It's the Snakes that are Pushing the Horses	Sono i Serpenti che Spingono i Cavalli
It's the Frogs that are Scratching the Pigs	Sono le Rane che Graffiano i Maiali
It's the Horses that are Scaring the Whales	Sono i Cavalli che Spaventano le Balene
It's the Seals that are Hitting the Frogs	Sono le Foche che Picchiano le Rane
It's the Dog that is Biting the Parrots	E' il Cane che Morde i Pappagalli
It's the Seal that is Chasing the Snakes	E' la Foca che Insegue i Serpenti
It's the Wolf that is Eating the Cows	E' il Lupo che Mangia le Mucche
It's the Whale that is Grabbing the Monkeys	E' la Balena che Afferra le Scimmie
It's the Bull that is Bumping the Wolves	E' il Toro che Colpisce i Lupi
It's the Cow that is Hurting the Dogs	E' la Mucca che Ferisce i Cani
It's the Cats that are Biting the Horse	Sono i Gatti che Mordono il Cavallo
It's the Whales that are Chasing the Snake	Sono le Balene che Inseguono il Serpente
It's the Dogs that are Eating the Eagle	Sono i Cani che Mangiano l' Aquila
It's the Goats that are Grabbing the Seal	Sono le Capre che Afferrano la Foca
It's the Pigs that are Bumping the Bull	Sono i Maiali che Colpiscono il Toro
It's the Monkeys that are Hurting the Wolf	Sono le Scimmie che Feriscono il Lupo

Passives *(Non-canonical O-V-S)*	
English	**Italian**
The Dog is Kicked by the Frog	Il Cane e' Calciato dalla Rana
The Seal is Pulled by the Fox	La Foca e' Tirata dalla Volpe
The Snake is Pushed by the Parrot	Il Serpente e' Spinto dal Pappagallo
The Eagle is Scratched by the Cat	L' Aquila e' Graffiata dal Gatto
The Bull is Scared by the Monkey	Il Toro e' Spaventato dalla Scimmia
The Frog is Hit by the Cow	La Rana e' Picchiata dalla Mucca
The Cats are Bitten by the Bulls	I Gatti sono Morsi dai Tori
The Foxes are Chased by the Pigs	Le Volpi sono Inseguite dai Maiali
The Dogs are Eaten by the Seals	I Cani sono Mangiati dalle Foche
The Goats are Grabbed by the Foxes	Le Capre sono Afferrati dalle Volpi
The Pigs are Bumped by the Parrots	I Maiali sono Colpiti dai Pappagalli
The Monkeys are Hurt by the Dogs	I Scimmie sono Feriti dai Cani
The Pig is Kicked by the Goats	Il Maiale e' Calciato dalle Capre
The Goat is Pulled by the Monkeys	La Capra e' Tirata dalle Scimmie
The Wolf is Pushed by the Horses	Il Lupo e' Spinto dai Cavalli
The Fox is Scratched by the Snakes	La Volpe e' Graffiata dai Serpenti
The Horse is Scared by the Eagles	Il Cavallo e' Spaventato dalle Aquile
The Monkey is Hit by the Frogs	La Scimmia e' Picchiata dalle Rane
The Bulls are Bitten by the Horse	I Tori sono Morsi dal Cavallo
The Cows are Chased by the Snake	Le Mucche sono Inseguite dal Serpente
The Parrots are Eaten by the Eagle	I Pappagalli sono Mangiati dall' Aquila
The Frogs are Grabbed by the Seal	Le Rane sono Afferrate dalla Foca
The Wolves are Bumped by the Pig	I Lupi sono Colpiti dal Maiale
The Eagles are Hurt by the Dog	Le Aquile sono Ferite dal Cane

Object Clefts *(Non-canonical O-S-V)*	
English	**Italian**
It's the Pig that the Horse is Biting	E' il Maiale che il Cavallo Morde
It's the Seal that the Parrot is Chasing	E' la Foca che il Pappagallo Insegue
It's the Snake that the Eagle is Eating	E' il Serpente che l' Aquila Mangia
It's the Frog that the Goat is Grabbing	E' la Rana che la Capra Afferra
It's the Parrot that the Horse is Bumping	E' il Pappagallo che il Cavallo Colpisce
It's the Eagle that the Wolf is Hurting	E' l' Aquila che il Lupo Ferisce
It's the Cats that the Wolves are Biting	Sono i Gatti che i Lupi Mordono
It's the Monkeys that the Parrots are Chasing	Sono le Scimmie che i Pappagalli Inseguono
It's the Dogs that the Goats are Eating	Sono i Cani che le Capre Mangiano
It's the Whales that the Foxes are Grabbing	Sono le Balene che le Volpi Afferrano
It's the Pigs that the Cats are Bumping	Sono i Maiali che i Gatti Colpiscono
It's the Whales that the Pigs are Hurting	Sono le Balene che i Maiali Feriscono
It's the Pig that the Seals are Kicking	E' il Maiale che le Foche Calciano
It's the Cow that the Monkeys are Pulling	E' la Mucca che le Volpi Tirano
It's the Dog that the Bulls are Pushing	E' il Cane che i Tori Spingono
It's the Cow that the Snakes are Scratching	E' la Mucca che i Serpenti Graffiano
It's the Horse that the Cows are Scaring	E' il Cavallo che le Mucche Spaventano
It's the Frog that the Whales are Hitting	E' la Rana che le Balene Picchiano
It's the Bulls that the Monkey is Kicking	Sono i Lupi che la Scimmia Calcia
It's the Seals that the Cow is Pulling	Sono le Foche che la Mucca Tira
It's the Horses that the Bull is Pushing	Sono i Cavalli che il Toro Spinge
It's the Frogs that the Cat is Scratching	Sono le Rane che il Gatto Graffia
It's the Bulls that the Whales are Scaring	Sono i Tori che la Balena Spaventa
It's the Cows that the Frog is Hitting	Sono le Mucche che la Rana Picchia

Appendix II

List of words and non-words used in the offline lexical decision task. Fifty English words were taken from Kucera and Francis (1967) database and 50 Italian words from the CoLFIS, corpus and frequency lexicon of written Italian **(**Laudanna, Thornton, Brown, Burani, & Marconi, 1995). Italian words had a mean frequency of 6.2 occurrences every three million (SD=5.0) and English words had a mean frequency of 10.0 per million (SD=6.4).

OFFLINE LDT - LIST OF WORDS						
Italian	**Length**	**Freq.**		**English**	**Length**	**Freq.**
fato	4	2		bow	3	15
acuto	5	8		jar	3	16
callo	5	5		Lid	3	19
cielo	5	2		oak	3	15
cruna	5	1		balm	4	0
felce	5	17		bulk	4	16
ghiro	5	3		colt	4	18
renna	5	2		curl	4	2
iodio	5	3		debt	4	13
spago	5	12		foil	4	20
zoppo	5	9		glow	4	16
bricco	6	4		gown	4	16
lembo	6	25		heap	4	14
medusa	6	5		lump	4	7
onesto	6	7		lung	4	16
pavone	6	10		meek	4	10
rasoio	6	21		pier	4	3
alterco	7	5		pill	4	15
anziana	7	4		scar	4	10
burrone	7	7		slab	4	9
castoro	7	6		toll	4	16
cerotto	7	5		wail	4	3
dipinto	7	11		weed	4	1
eremita	7	9		weir	4	2
fiatone	7	2		brand	5	17
funivia	7	5		dough	5	13
inutile	7	3		drift	5	18
ovatta	6	4		layer	5	12
relitto	7	15		letch	5	19
salasso	7	2		mould	5	1
sughero	7	6		patch	5	13
ventola	7	2		ridge	5	18
adultero	8	4		scent	5	6
amaranto	8	2		shunt	5	1
biliardo	8	9		spear	5	7
ermetico	8	10		stitch	6	3

focaccia	8	3	stoat	5	0
fumogeno	8	4	stool	5	8
randello	8	2	fringe	6	16
spazzino	8	4	linger	6	7
bucaniere	9	2	meadow	6	17
portinaio	9	3	praise	6	17
arcobaleno	10	7	ribbon	6	12
fiammifero	10	11	squire	6	5
lampadario	10	7	strand	6	7
antonomasia	11	4	strife	6	6
indossatore	11	1	trench	6	2
maldicenza	10	4	cushion	7	8
parrucchiera	12	7	skipper	7	1
stuzzicadenti	13	6	sulphur	7	3

OFFLINE LDT - LIST OF NON-WORDS			
Italian	**Length**	**English**	**Length**
mato	4	rop	3
amure	5	dend	4
ecnia	5	fusk	4
madro	5	heil	4
olgio	5	slor	4
ronzo	5	soam	4
annera'	6	sorl	4
arrovi	6	chaum	5
britto	6	crolt	5
meloso	6	feise	5
poscio	6	feuld	5
rionda	6	greeb	5
tocino	6	prous	5
umarto	6	snoch	5
zandria	6	whols	5
corfito	7	wiers	5
ettavio	7	smerch	6
nariosa	7	sporns	6
porlana	7	squaul	6
riverco	7	stilch	6
flattico	8	stintz	6
sendonio	8	trales	6
agnostimo	9	wrourt	6
ginecriolo	10	kneulls	7
cionfiscato	11	wraughs	7

A list of 50 English words with a mean frequency of 46.7 (SD=14.1) occurrences per million were taken from the Kucera and Francis (1967) database and translated into Italian equivalents (e.g., *Mayor* = *Sindaco*). Fifty plausible non-words were also created for both languages (see Chapter 7 for more details).

ONLINE LDT - LIST OF WORDS				
English	**Length**	**Freq.**	**Italian**	**Length**
bag	3	43	borsa	5
beach	5	61	spiaggia	8
bear	4	57	orso	4
belt	4	29	cintura	7
bench	5	35	panchina	8
blind	5	47	cieco	5
boat	4	72	barca	5
bone	4	33	osso	4
box	3	70	scatola	7
brain	5	45	cervello	7
brush	5	44	spazzola	8
chain	5	50	catena	6
chair	5	66	sedia	5
chest	5	53	petto	5
chin	4	27	guancia	7
cloth	5	43	straccio	7
cloud	5	28	nuvola	6
coal	4	32	carbone	7
cow	3	29	mucca	5
crowd	5	53	gente	5
cup	3	45	tazza	5
dawn	4	28	alba	4
desk	4	65	tavolo	6
draw	4	56	disegno	7
dress	5	67	vestito	7
ear	3	29	orecchio	8
fence	5	30	siepe	5
foam	4	37	schiuma	7
fog	3	25	nebbia	6
frame	5	74	cornice	7
gate	4	37	cancello	7
gift	4	33	regalo	6
grass	5	53	erba	4
hat	3	56	cappello	8

hill	4	72	collina	7
hole	4	58	buco	4
horn	4	31	corno	5
ice	3	45	ghiaccio	7
knee	4	35	ginocchio	9
mail	4	47	posta	5
mayor	5	38	sindaco	7
paint	5	37	vernice	7
ring	4	47	anello	6
roof	4	59	tetto	4
root	4	30	radice	6
snow	4	59	neve	4
throat	6	51	gola	4
travel	6	61	viaggio	7
tree	4	59	albero	6
wheel	5	56	ruota	5

ONLINE LDT - LIST OF NON-WORDS			
English	**Length**	**Italian**	**Length**
heg	3	dela	4
kly	3	lano	4
larn	3	nala	4
wat	3	nito	4
bick	4	podo	4
boad	4	rama	4
cipe	4	sufo	4
dalt	4	biala	5
dath	4	borta	5
domb	4	dacco	5
ench	4	digno	5
foat	4	gesca	5
geef	4	gilza	5
gond	4	mervo	5
jelf	4	nampa	5
jile	4	nazza	5
jore	4	omido	5
keer	4	rulce	5
kell	4	runta	5
lage	4	sepre	5
leat	4	tolpe	5
mand	4	baiale	6
mard	4	boneta	6

namp	4	dancia	6
nath	4	danica	6
pome	4	ledone	6
quet	4	pegola	6
rill	4	pivano	6
rize	4	poglia	6
sape	4	rimone	6
sast	4	talvia	6
sird	4	tranio	6
wock	4	zarile	6
wold	4	bistola	7
wope	4	cicchio	7
clain	5	daraffa	7
datch	5	gettine	7
gaint	5	golomba	7
grank	5	praccio	7
hond	5	rambola	7
jeath	5	rattera	7
kuard	5	rollice	7
loast	5	rostola	7
loute	5	terenda	7
meard	5	toccolo	7
norch	5	tracchi	7
purve	5	faviglia	8
tirth	5	goffitta	8
tuide	5	priciola	8
frince	6	ricatrice	9

Appendix III

List of stimuli used in the switching in production word naming experiment. English words were taken from the MRC Psycholinguistic Database, (Coltheart, 1981) using the indices of word frequency (Kucera & Francis, 1967) and concreteness (Coltheart, 1981); Italian words were taken from the *Corpus e Lessico di Frequenza dell'Italiano Scritto* - CoLFIS **(**Laudanna, Thornton, Brown, Burani, & Marconi, 1995). Words were split in two groups of 15 by their class, i.e., singles, cognates and homographs, and used as a switch and non-switch according to the presentation order (see Chapter 9 for the design). Words were balanced by their length, frequency and concreteness within each language (t-tests always non-significant: p>.05).

			ITALIAN SINGLES					
No.	**Words**	**Length**	**Frequency**	**Concr.**	**Words**	**Length**	**Frequency**	**Concr.**
1	BENE	4	500	297	MONDO	5	500	532
2	MORTE	5	500	365	BAMBINO	7	500	589
3	BURRO	5	91	500	CUCINA	6	271	n/a
4	GIOVANE	7	500	n/a	TERRA	5	500	580
5	SANGUE	6	473	613	DOMANDA	7	500	387
6	AZIENDA	7	500	389	CANZONE	7	330	514
7	SALIRE	6	500	355	SORELLA	7	332	575
8	VENDERE	7	482	342	MELA	4	66	620
9	EBETE	5	1	354	REMO	4	15	n/a
10	FICO	4	16	n/a	RENE	4	24	n/a
11	SPOSA	5	91	n/a	TELA	4	97	n/a
12	AMO	3	24	500	BUCA	4	27	485
13	FOSSA	5	29	500	ALGA	4	25	593
14	TAPPO	5	22	608	EREMO	5	7	367
15	RUPE	4	9	500	ORMA	4	25	464
	MEDIAN	**5**	**91**	**445**		**5**	**97**	**532**

		ENGLISH SINGLES					
Words	**Lenght**	**Frequency**	**Concr.**	**Words**	**Lenght**	**Frequency**	**Concr.**
TIME	4	500	343	BECAUSE	7	500	196
BECAME	6	246	273	SAME	4	500	248
CABBAGE	7	4	611	CLOVE	5	1	565
COMRADE	7	4	497	BRIBE	5	1	367
DESPISE	6	7	314	ACHE	5	4	433
RESTORE	7	9	275	TASTE	5	59	464
SLICE	5	13	433	ELSE	4	176	222
LOSE	4	58	299	SURFACE	7	200	447
MOUSE	5	10	624	ENGINE	6	50	586
FAILURE	7	89	282	OUTCOME	7	26	318
SMILE	5	58	514	FIRE	4	187	595
GIVE	4	391	326	FIVE	4	286	365
SEA	3	95	596	RULE	4	73	286
FRAME	5	74	562	SORE	4	10	502
GAME	4	123	477	NINE	4	81	452
	5	**58**	**433**		**5**	**73**	**433**

ITALIAN COGNATES							
Words	**Length**	**Frequency**	**Concr.**	**Words**	**Length**	**Frequency**	**Concr.**
ME	2	500	511	IDEA	4	500	259
CINEMA	6	500	n/a	HOTEL	5	61	591
MINE	4	5	452	ZOO	3	31	583
DOSE	4	133	n/a	FINALE	6	294	n/a
SOFA	4	11	629	VETO	4	36	326
VILE	4	18	379	COSTUME	7	179	544
SCENARIO	8	93	n/a	ORCHESTRA	9	168	578
MEDICINE	8	57	192	RARE	4	199	327
FORMULA	7	149	n/a	VOLUME	6	199	418
MISSILE	7	70	597	PAUSE	5	109	306
SCENE	5	500	408	ACETONE	7	2	n/a
NOTE	4	2	525	ROSE	4	2	608
BASE	4	372	441	AREA	4	483	384
SANE	4	122	290	CURE	4	2	325
ZONE	4	3	392	AUDIO	5	4	n/a
MEDIAN	**4**	**93**	**441**		**5**	**109**	**401**

ENGLISH COGNATES							
Words	**Length**	**Frequency**	**Concr.**	**Words**	**Length**	**Frequency**	**Concr.**
ME	2	500	511	ZOO	3	9	583
AREA	4	323	384	SOFA	4	6	629
RARE	4	4	327	ZONE	4	11	392
NOTE	4	127	525	SANE	4	8	290
AUDIO	5	2	n/a	SCENE	5	106	408
PAUSE	5	21	306	VOLUME	6	135	418
FINALE	6	6	n/a	HOTEL	5	126	591
COSTUME	7	10	544	FORMULA	7	59	n/a
VILE	4	5	379	ORCHESTRA	9	60	578
MEDICINE	8	30	517	CURE	4	28	325
MINE	4	59	452	BASE	4	91	441
IDEA	4	195	259	ROSE	4	86	608
MISSILE	7	48	597	VETO	4	10	326
CINEMA	6	3	n/a	DOSE	4	11	n/a
SCENARIO	8	1	n/a	ACETONE	7	4	n/a
	5	**21**	**452**		**4**	**28**	**429**

ITALIAN HOMOGRAPHS							
Words	**Length**	**Frequency**	**Concr.**	**Words**	**Length**	**Frequency**	**Concr.**
FARE	4	500	276	COME	4	500	195
MORE	4	11	n/a	DUE	3	500	383
FILE	4	40	n/a	DOVE	4	304	256
CUTE	4	20	614	SALUTE	6	317	372
CAMERA	6	500	566	ONCE	4	1	502
DARE	4	500	326	SALE	4	206	594
PANE	4	187	622	FAME	4	174	410
CANE	4	328	610	SOLE	4	485	617
FINE	4	500	320	SCALE	5	92	558
RATE	4	25	n/a	MOBILE	6	162	583
MALE	4	456	308	PACE	4	401	309
CARE	4	19	326	CASE	4	315	608
ESTATE	6	500	439	PILE	4	1	n/a
CHINA	5	14	608	ALONE	5	15	n/a
APE	3	42	597	PIE	3	2	n/a
MEDIAN	**4**	**187**	**503**		**4**	**255**	**456**

ENGLISH HOMOGRAPHS							
Words	**Length**	**Frequency**	**Concr.**	**Words**	**Length**	**Frequency**	**Concr.**
APE	3	3	654	PIE	**3**	14	613
MOBILE	6	44	n/a	FINE	4	161	328
PANE	4	3	506	DUE	3	150	n/a
DOVE	4	4	588	FARE	4	7	413
CAMERA	6	36	627	CANE	4	12	590
SALUTE	6	3	471	SOLE	4	18	484
DARE	4	21	291	MORE	**4**	500	284
SALE	4	44	364	FAME	4	18	n/a
ONCE	**4**	499	315	PACE	4	43	n/a
CUTE	4	5	n/a	MALE	4	37	564
RATE	**4**	209	308	PILE	4	25	504
CARE	**4**	162	342	CASE	**4**	362	548
ALONE	5	150	390	COME	4	500	355
FILE	4	81	480	ESTATE	6	51	541
CHINA	5	69	578	SCALE	**5**	60	475
	4	**44**	**471**		**4**	**43**	**494**

Appendix IV

Language history questionnaire adapted from Li, Sepanski and Zhao (2006)

Date: ___/___/___
Name: ____
Surname: ____
Email: ______________________Telephone: __________________

Please answer the following questions to the best of your knowledge

1. Date of Birth: ___/___/___

2. Gender: Male / Female

3. Education (the highest obtained or in the process to be obtained):

____

4.Profession (current role):

5(a). Country of origin: ______________________________________

5(b). Country of Residence:____________________________________

6(a). If 5(a) and 5(b) are the same, how long have you lived in a foreign country where your second language is spoken? (in years) ____________________

6(b). If 5(a) and 5(b) are different, how long have you been in the country of your current residence? (in years) ____________________________________

7a. What is your native language?

____

7b. What is your second language?

____

7c. If you speak more than two languages, please specify
____

8. Please specify the age at which you started to learn your second language in the following situations (write age next to any situation that applies).

Since birth: __________

At home: __________

In school: __________

After arriving in the second language speaking country _________

9. How did you learn your second language up to this point? (check all that apply)

Almost only / **Mostly** / **Occasionally** through formal classroom instruction.

Almost only / **Mostly** / **Occasionally** through interacting with people.

A mixture of both, but **More classroom** **More interaction** **Equally both**

Other (**specify:** ____).

10. List all foreign languages you know in order of most proficient to least proficient. Rate your ability on the following aspects in each language. Please rate according to the following scale (write down the number in the table):

Very poor	Poor	Functional	Good	Very good	Native-like
1	**2**	**3**	**4**	**5**	**6**

Language	Reading proficiency	Writing proficiency	Speaking fluency	Listening ability

11. Provide the age at which you were first exposed to each foreign language in terms of speaking, reading, and writing, and the number of years you have spent on learning each language.

Language	Age first exposed to the language			Number of years learning
	Speaking	Reading	Writing	

12. Do you have a foreign accent in the languages you speak? If so, please rate the strength of your accent according to the following scale (write down the number in the table):

No Accent	Very Weak	Weak	Intermediate	Strong	Very Strong
1	**2**	**3**	**4**	**5**	**6**

Language	Accent (circle one)	Strength
	Y N	
	Y N	
	Y N	
	Y N	
	Y N	

PART B

13. Estimate, in terms of percentages, how often you use your native language and other languages per day (in all daily activities combined, circle one that applied):

Native language:	25% or less	50%	75%	100%
Second language:	25% or less	50%	75%	100%
Other languages:	25% or less	50%	75%	100%

(specify the languages: ____________________)

14. Estimate, in terms of hours per day, how often you are engaged in the following activities with your native and second languages.

Activities	First Language	Second Language	Other Languages (specify _______)
Listen to Radio/ Watching TV:	_______(hrs)	_______(hrs)	_________(hrs)
Reading for fun:	_______(hrs)	_______(hrs)	_________(hrs)
Reading for work:	_______(hrs)	_______(hrs)	_________(hrs)
Reading on the Internet:	_______(hrs)	_______(hrs)	_________(hrs)
Writing emails to friends:	_______(hrs)	_______(hrs)	_________(hrs)
Writing articles/papers:	_______(hrs)	_______(hrs)	_________(hrs)

15. Estimate, in terms of hours per day, how often you speak (or used to speak) your native and second languages with the following people.

	Language	Hours
Father:	______________________	_____________(hrs)
Mother:	______________________	_____________(hrs)
Grandfather(s):	______________________	_____________(hrs)
Grandmother(s):	______________________	_____________(hrs)
Brother(s)/Sister(s):	______________________	_____________(hrs)
Other family members:	______________________	_____________(hrs)

16. Estimate, in terms of hours per day, how often you now speak your native and second languages with the following people.

	Language	Hours
Spouse/partner:	______________________	_____________(hrs)
Friends:	______________________	_____________(hrs)
Classmates:	______________________	_____________(hrs)
Co-workers:	______________________	_____________(hrs)

17. Write down the name of the language in which you received instruction in school, for each schooling level:

Primary/Elementary School: ______________

Secondary/Middle School: ______________

High School: ______________

College/University: ______________

18. In which languages do you usually:

Count, add, multiply, and do simple arithmetic? ________________

Dream? ________________

Express anger or affection? ________________

19. When you are speaking, do you ever mix words or sentences from the two or more languages you know? (If no, skip to question 21).

____

20. List the languages that you mix and rate the frequency of mixing in normal conversation with the following people according to the following scale (write down the number in the table):

Rarely	Occasionally	Frequently	Very Frequently
1	**2**	**3**	**4**

Relationship	Languages mixed	Frequency of mixing
Spouse/family members		
Friends		
Co-workers		
Classmates		

21. In which language (among your best two languages) do you feel you usually do better? Write the name of the language under each condition.

	At home	**At work**
Reading	______________	______________
Writing	______________	______________
Speaking	______________	______________
Understanding	______________	______________

22. Among the languages you know, which language is the one that you would prefer to use in these situations?

At home ____________________
At work ____________________
At a party ____________________
In general ____________________

23. If you have lived or travelled in other countries for more than three months, please indicate the name(s) of the country or countries, your length of stay, and the language(s) you learned or tried to learn.

____
____
____
____

24. If you have taken a standardised test of proficiency for languages other than your native language (e.g. TOEFL - Test of English as a Foreign Language), please indicate the scores you received for each.

Language	**Scores**	**Name of the Test**
_______________	____________	________________________
______________	____________	________________________
_______________	____________	________________________

25. If there is anything else that you feel is interesting or important about your language background or language use, please comment below.

____
____
____
____
____
____

Appendix V

Language history questionnaire adapted from Tokowicz, Michael & Kroll, 2004).

This questionnaire is designed to give us a better understanding of your child's experience with languages.

PLEASE COMPLETE THE QUESTIONNAIRE ALSO IF YOUR CHILD SPEAKS ONLY ENGLISH

We ask that you be as accurate and thorough as possible when answering the following questions and we thank you for your participation in this study.

Child's name: ____ Gender: M / F

Child's date of birth (Day/Month/Year):___/____/_____

Native Country: _______________________________________

1. What is your child's NATIVE language (i.e. the language FIRST spoken)? If more than one, please list each one:

   a) FIRST Language___________________________________
   b) SECOND Language___________________________________
   c) OTHERS____

IF YOUR CHILD SPEAKS ONLY ENGLISH, PLEASE JUST ANSWER QUESTIONS 13, 17 and 18.

2. Which language does your child consider his/her SECOND language? (i.e. a SECOND language is the one which your child may be less fluent in)

____

3. What was the main purpose for learning or acquiring his/her SECOND language?

   a) Language in country of residence
   b) School
   c) Parents speaking different languages
   d) Other______________________

4. Has your child ever been immersed in his/her second language culture? (i.e. living or studying in a country where that language is the main language spoken)

____

5. Estimate, in terms of hours per day, how often your child speak his/her native and second languages with the following people.

	Language	**Hours**
Father:	______________________	_____________(hrs)
Mother:	______________________	_____________(hrs)
Grandfather(s):	______________________	_____________(hrs)
Grandmother(s):	______________________	_____________(hrs)
Brother(s)/Sister(s):	______________________	_____________(hrs)
Other family members:	______________________	_____________(hrs)

6. In which language does your child usually:

Count, add, multiply, and do simple arithmetic? ________________
Dream? ________________
Express anger or affection? ________________

7. Does your child switch languages in mid sentence? **Yes______ No_______**

8. Does your child experience difficulties finding words in one of his/her languages and insert words from the other? **Yes_______ No _________**

9. Did your child hear a second language during infancy before he could speak and then no longer heard it? **Yes ______ No_______**

10. Does your child know nursery rhymes or hymns? **Yes______ No_______**

11. If so, in which of his/her language(s)?
   a. ______________
   b. ______________
   c. ______________
   d. ______________

12. Estimate, in terms of hours per day, how often your child is engaged in the following activities using his/her native and second languages.

Activities	**First Language**	**Second Language**	**Other Languages (specify _______)**
Listen to Radio/ Watching TV:	_______(hrs)	_______(hrs)	_________(hrs)
Reading for fun:	_______(hrs)	_______(hrs)	_________(hrs)
Reading for study:	_______(hrs)	_______(hrs)	_________(hrs)
Reading on the Internet:	_______(hrs)	_______(hrs)	_________(hrs)

13. Please rate your child's ability in all the languages he/she knows, **starting with the MOST fluent**. You should rate your child's abilities in all aspects of language (reading, writing, speaking and comprehension) using the scale below. Please include all languages to which your child has been exposed even if he/she may never have had formal teaching in them and may not be able to read, speak or write them.

First language: ____________________ (state language)

	not literate/fluent								***very literate/fluent***
Reading	1	2	3	4	5	6	7	8	9	10
Writing	1	2	3	4	5	6	7	8	9	10
Speaking	1	2	3	4	5	6	7	8	9	10
Comprehension	1	2	3	4	5	6	7	8	9	10

Second language: ____________________ (state language)

	not literate/fluent								***very literate/fluent***
Reading	1	2	3	4	5	6	7	8	9	10
Writing	1	2	3	4	5	6	7	8	9	10
Speaking	1	2	3	4	5	6	7	8	9	10
Comprehension	1	2	3	4	5	6	7	8	9	10

Third language (if applicable): ____________________ (state language)

	not literate/fluent								***very literate/fluent***
Reading	1	2	3	4	5	6	7	8	9	10
Writing	1	2	3	4	5	6	7	8	9	10
Speaking	1	2	3	4	5	6	7	8	9	10
Comprehension	1	2	3	4	5	6	7	8	9	10

Fourth language (if applicable): ____________________ (state language)

	not literate/fluent								***very literate/fluent***
Reading	1	2	3	4	5	6	7	8	9	10
Writing	1	2	3	4	5	6	7	8	9	10
Speaking	1	2	3	4	5	6	7	8	9	10
Comprehension	1	2	3	4	5	6	7	8	9	10

14. Please list any languages spoken in your child's immediate environment which is not listed above?

____

15. Provide the age at which your child was first exposed to each foreign language in terms of speaking, reading, and writing.

Language	**Age first exposed to the language**			**Number of years learning**
	Speaking	**Reading**	**Writing**	

16. Has your child ever lived or visited a country (other than on short holidays) where languages other than your native language were spoken? Please indicate the country, the duration of your stay in number of months, and which languages your child spoke or was exposed to whilst there.

Country Visited	**Duration (in months)**	**Language(s) used/heard**

PARENT'S SECTION

17. What is the FIRST language of the child's parents?

Mother: ___________________________ Father: ______________________

18. Please state the level of education of the child's parents

- Primary school
- Secondary school
- Higher education/University

Mother: ___________________________ Father: ____________________

Thank you for completing this questionnaire!

APPENDIX VI

Study 6: Figure VI.1 displays the participants' distribution in terms of levels of cognitive-academic proficiency in English, which was categorised according to 6 different levels ranging from very limited to advanced.

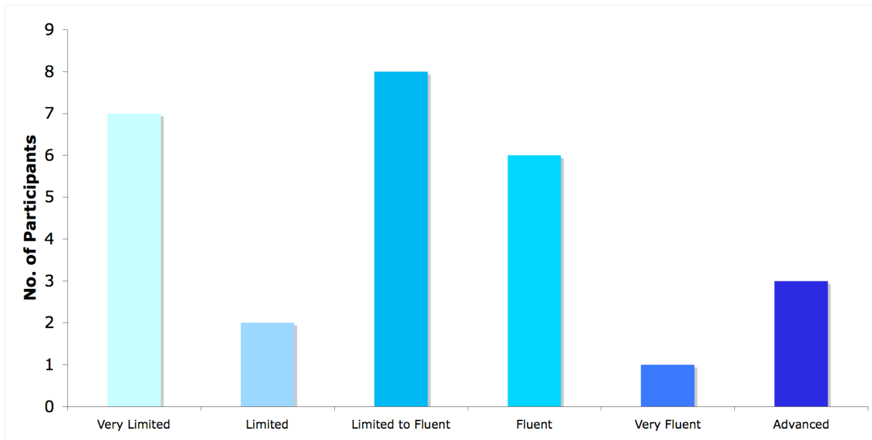

Figure VI.1: Participants' levels of proficiency in English assessed with the Bilingual Verbal Ability Tests (BVAT).

For the lexical decision tasks, the participants' performance is reported in Table VI.2 both in terms of reaction times (online task only) and percent accuracy (offline and online tasks).

Table VI.2: Participants' mean RTs (seconds) and accuracy (%) in the online and offline lexical decision tasks

Task	Stimuli	Mean	SD
Offline LDT English	% CR Words	87	10
	% CR Non-Words	80	16
Offline LDT Italian	% CR Words	97	5
	% CR Non-Words	87	15
Online LDT English	% CR Words	94	4
	% CR Non-Words	84	16
Online LDT Italian	% CR Words	98	2
	% CR Non-Words	93	8
Online LDT English	RT Words	0.61	0.07
	RT Non-Words	0.82	0.17
Online LDT Italian	RT Words	0.61	0.11
	RT Non-Words	0.80	0.17

A series of 2x2 analyses of variance for language (English, Italian) and stimuli (words, non-words) from the lexical decision tasks, overall showed that the bilinguals' dominant language was Italian. All participants were more accurate with words than non-words when performing the task in Italian in both offline and online lexical decision tasks when they performed them in their native language [offline, main effect of language=$F(1,26)=8.194$, $p=.008$, $\eta^2=.240$, main effect of stimuli= $F(1,26)=21.663$, $p<.001$, $\eta^2=.454$; online, main effect of language=$F(1,26)=10.877$, $p=.003$, $\eta^2=.295$, main effect of stimuli=$F(1,26)=31.019$, $p<.001$, $\eta^2=.544$]. A reliable interaction between language and stimuli, $F(1,26)=5.010$, $p=.034$, $\eta^2=.162$, revealed that bilinguals were more accurate with plausible non-words when performing the online task in Italian than in English, but the same interaction was non significant in the offline task, $F(1,26)=.663$, $p=.423$, $\eta^2=.025$.

For reaction times in the online lexical decision task, bilinguals were 0.2 second significantly faster in Italian than in English, $F(1,26)=54.596$, $p<.001$, $\eta^2=.677$, but had equal performance with words and non-words, $F(1,26)=.212$, $p=.649$, $\eta^2=.008$. There was no interaction between language and stimuli, $F(1,26)=.137$, $p=.715$, $\eta^2=.005$, showing that bilinguals' lexical decision was comparable in both languages for words and non-words.

In summary, participants' lexical access and vocabulary knowledge was better when the two lexical decision tasks were performed in their native language, Italian.