Bilingualism and Cognitive Control

Ramesh Kumar Mishra

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Preface

It is well-recognised that any serious practice of a demanding skill over a period of time should change the brain: cognitive neuroplasticity could emerge because of long and persistent training. In this book I propose that the practice of bilingualism could lead to such noticeable advantageous neuroplasticity lifelong. Much research has shown that people who are bilingual enjoy a cognitive advantage in attention and executive control over those who are monolingual. This book, which is published in Springer’s book series on bilingualism, summarises these results and contextualises them in light of current debates. Currently, no book-length discussions of bilingualism and cognitive control exist. The state-of-the-art coverage is aimed at students and researchers in multiple domains, including psycholinguistics, cognitive science, cognitive neuroscience and neurolinguistics among others. This book is divided into several chapters that stand alone, each of which has been designed to offer in-depth analysis of one issue within the context of bilingualism and cognition.

Considering the fact that the beneficial effects of bilingualism on cognition are currently under intense scrutiny and debate, I have attempted to show what we know for sure as of now. More controversial issues are also discussed so as to offer the reader the opportunity to create their own interpretations. This topic is of interest since we want to know whether speaking two languages makes us better than such things as taking pills or doing a difficult sport. Also, does this cognitive benefit also extend to domains where one does not need any language? Currently, scientists stand divided on the issue of bilingualism and its precise impact on our general cognition. Does bilingualism change the structural and functional patterns of the brain to such an extent that its functioning becomes much faster and smarter on a range of difficult tasks and other challenges of life? Additionally, there are differences of opinion on the exact psycholinguistic processes in bilinguals that allows recruitment of such control mechanisms. The chapters of this book cover dominant theories and modes, including empirical data, that exemplify the issues.

The book is written in the style of a monograph; therefore, chapters are not introductory. There are many excellent textbooks on bilingualism and related issues. However, at this point in time, there are many shortcomings in the field, some of
which are methodological. For example, we have only managed to study bilinguals in specific locations, mostly university students. The enormous influence of the sociolinguistic and cultural context on bilingual cognition is only now being appreciated. However, newer methods bring their own problems for analysis and interpretation, although they advance the field. Bilingual illiterates, who still inhabit many regions of the world, have not been studied. For example, India still has a sizable number of people who are formally illiterate but are bilinguals. In addition, individual differences and how they might explain the bilingualism cognition interface has not been looked at carefully. What I have written in this book should be interpreted keeping these points in mind.

I have researched cognitive control in Indian bilinguals and I discuss this research at many points throughout this book. Whether bilingualism has an effect on cognition or not, it is clear that this is a very heterogeneous problem. My own research has shown the difference between second-language speakers of high and low proficiency on different executive control tasks. In this monograph, I demonstrate this heterogeneity in research results with cross-linguistic comparisons. The last chapter of the book offers a detailed summary of the main points and also future directions for research in this area.

Hyderabad, India
Ramesh Kumar Mishra
3 March 2018
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I have benefited much from collaborative associations with many remarkable scholars during my research on bilingualism. Raymond Klein (Dalhousie University, Canada) has played an important role in shaping my thinking through collaborations with Jean Saint-Aubin (University of Moncton, Canada). I also have interacted with Debra Titone (McGill University, Canada) and learnt much about bilingualism and diversity. I am thankful to Thomas Wynn (University of Colorado, USA) and Yanjing Wu (Bangor University, Wales) who have read selected chapters and commented. I hope I have been able to incorporate their suggestions. I also thank the series editors Roberto Heredia (Texas A&M International University, USA) and Anna Cieślicka (Texas A&M International University) who have been very helpful with their advice since the project took shape and also for providing comments on the draft. Thanks are due to Morgan Ryan and Sara Yanny-Tillar from Springer whose timely comments immensely helped in finishing the project. I have spoken about the research that finds a place in this book at many talks and seminars and the questions and discussions have enriched my understanding of the concepts.

Writing a book takes a great amount of time and energy. At the Centre for Neural and Cognitive Sciences, University of Hyderabad, India, I found a very conducive atmosphere. I have learnt much from the excellent PhD students who are working on bilingualism. Most particularly I thank Seema Prasad, my PhD student who has provided much help in manuscript preparation and editing. I thank my wife Bidisha and daughter Riya for all their support during the entire course of writing the book.

Hyderabad, India

Ramesh Kumar Mishra
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About the Author

Ramesh Kumar Mishra is a cognitive scientist and chair of the Center for Neural and Cognitive Sciences at the University of Hyderabad, a major research university in India. He has published widely in the areas of attention, visual processing, bilingualism and language processing. He has also published on literacy and its influence on cognition. He has edited or authored three books (Mishra 2015; Mishra Huettig & Srinivasan 2015; Mishra & Srinivasan 2011; Mani, Mishra & Huettig (in press)) to date in the area of language–vision interaction. He is also an editorial board member of the journal Bilingualism: Language and Cognition. His dual expertise in cognitive psychology (attention, vision and executive control) and psycholinguistics of bilingualism (language non-selective activation, visual world eye tracking) helps him to explore in-depth the cognitive science angle to the bilingual advantage effect. He is the Editor-in-Chief of the International Journal of Cultural Cognitive Science (Springer) and is a fellow of the Psychonomic Society.

References

Chapter 1
Introduction

Introductions to academic books are about what the book contains and why the author has written it. I have written this book because I am deeply interested in bilingualism as a model for the mind and brain. I also believe that this model can explain much about our linguistic and other forms of cognition. This book focuses on the question of bilingualism, its practice and its possible cognitive consequences. I consider this book timely since much is happening in the field of bilingualism that is both controversial and illuminating. The term ‘cognitive influences’ is very broad and diverse. Most scholars and graduate students who are acquainted with this literature will narrow it down to executive control functions—a set of higher-order mental functions that allow us our grip over our action and thought. A key question has been whether these set of functions are modulated by the practice of bilingualism to the extent that they start becoming better and better in bilinguals. The book began as a stock-taking enterprise on the myriad issues related to such neuroplasticity caused by bilingualism. Both the psycholinguistics and cognitive psychology including cognitive neuroscience investigations into bilingualism are highly evolved areas within cognitive sciences today. Considering the diverse range of ideas and debates in this field, the chapters of the book reflect that complexity. It is not an introductory book. The book does not attempt a straightforward review of what we know so far. Instead, it explores the various theoretical issues related to the question of cognitive advantage as a function of bilingualism and important controversies. It offers discussions and critique of the most recent studies in this area from different participating disciplines, including those from cognitive psychology, cognitive neuroscience and psycholinguistics among others. I do not address whether bilingualism should influence executive functions, but focus on the constraining factors.

This is not the first book on the question of bilingualism or its cognitive implications. There have been many excellent textbooks and specialised books in these areas (e.g. De Groot, 2011; Kroll & De Groot, 2009; Schwieter, 2016). Schwieter (2016) has published many recent chapters on the issue of control. The books by Grosjean (1982, 1989) are excellent introductions to bilingualism. These books alert students to both psycholinguistics and cognitive psychological issues related to
bilingual language control and cognition. I strongly recommend that beginning students read them to acquire the background that will allow him/her to evaluate my claims in a better informed manner. However, to date, a full-length intense treatment of cognitive control and bilingualism was missing apart from several review articles in journals (Bialystok, 2017, 2018). This is a particularly exciting time since the very question is under attack and many researchers think that the advantage is an artefact (Paap & Greenberg, 2013). The primary audience of this book is students in fields such as linguistics, cognitive science and neuroscience. The researchers in the field who directly work in this area and whose works I cite will either agree or disagree with my assertions. Departing from the conventional approaches, I have included a chapter on the evolutionary underpinnings of bilingual behaviour in our species and also on the influence of social context on language control. Of course, the running theme that connects all the chapters is the issue of bilingualism and its possible impact on executive control.

The idea that speaking two languages has some influence on executive control has an interesting history. A few decades ago researchers believed that bilingualism may, in fact, have a negative effect on a child’s intelligence or cognition. For example, in her review, Darcy (1963) noted that bilingualism may not be that good after all for sound development of intelligence. Pearl and Lambert (1962) were the first to conduct a systematic comparison between bilinguals and monolinguals and found that bilinguals were better on non-verbal and verbal tasks. In particular, the bilinguals were better at tasks that called for higher mental flexibility. Since then, most prominently the research by Bialystok & Martin (2004) have consistently found that bilingual children show superior cognitive abilities than monolingual children on tasks that call for conflict resolution. David Green’s (1998) inhibitory control model directly linked the psycholinguistics of language control with inhibitory control in bilinguals. Since then, cognitive psychologists have tested hundreds of bilinguals around the world against monolinguals on all kinds of tasks ranging from attention, memory and perception to mental flexibility. Thus, the field has evolved over a period of time with collaborative contributions of psycholinguists, cognitive psychologists and now cognitive neuroscientists who explore brain dynamics. Today the question has narrowed down to what extent, if any, bilingualism influences particular components of executive control. Although I do not cover this interesting history in this book, current opinions and controversies stand on these early critical observations. Grosjean (2010) offers a highly readable and scholarly overview of the field and breaks down some myths about bilinguals and bilingualism. The field has also seen much media enthusiasm and coverage on the issue (see, for example, “Is Bilingualism Really an Advantage?” in The New Yorker, 22 January 2015).

One of my underlying assumptions in this book is that we still don’t understand many of the issues related to bilingualism and cognition. Existing facts remain unreconciled and pose many more questions than they answer. While data are discussed in the chapters, my narrative is more geared towards asking questions that remain to be answered. Foundational among them is what it is exactly that bilinguals do when we say that they are controlling their languages? How do different bilinguals differ on these very mechanisms? What role does executive control play
in this mechanism? What is the role of culture in this interaction between bilingualism and cognition? Why do proficient bilinguals that know both languages well still show spontaneous translation in laboratory tasks? How is non-selective language activation influenced by executive control? Many of these questions are psycholinguistic in nature.

Much of my own experimental work on bilinguals has been in India with Indian bilinguals (Singh & Mishra, 2012, 2013, 2015, 2016). Does it matter where you study bilinguals? I later show that linguistic, ethnic and cultural variables directly affect both the cognitive and neurobiology of bilingualism. Studying bilingualism in India can be very enriching and also challenging, unlike in other places. First of all, India has around 1500 spoken languages and innumerable dialects (Mohanty & Babu, 1983). English in India has played a key role in shaping its overall bilingualism (Sridhar, 1989). Apart from the mainstream languages, there are many tribal languages spoken by indigenous people who may be few in number. Not all such languages have scripts. Further, given that there are four language families and many ethnic groups who speak them, in the Indian context bilingualism is also bicultural and at times bيسcriptal.

English is one of the official languages in India and is learned at school. All post-school education is in English, barring a few places where the regional language of the state is used. Interestingly, the few studies on Indian bilingualism from a psycholinguistic or cognitive science perspective have been on bilinguals with English as a second language. Therefore, the subjects are mostly university educated students or older adults. Compared to this situation, there is little variation within bilingualism in other countries such as the USA or Canada. Furthermore, most Indians learn three languages at school: Hindi, English and a provincial language. This makes most educated Indians multilingual. Therefore, studying the psycholinguistic nature of bilingualism in India could pose issues that may not occur elsewhere. In my work, I have studied mostly university students who have English as their second language. Based on their length of study and experience, their proficiency in English varies markedly. I have often taken language proficiency as a grouping variable. In India, one can find many bilinguals who may be well-versed in two different Indian languages belonging to two different language families. Therefore, what we know about, for example, Hindi–English or Telugu–English bilinguals can’t be generalised to such other bilinguals without several assumptions. Since most such bilinguals can also read and write in these languages, this influences language selection and control. India still has a large percentage of people who are illiterate; however, they know two different languages without corresponding literacy knowledge. How literacy level affects bilingualism is not known. Given this backdrop, generalisations from studies must be understood within these constraints.

My studies have reported high proficient bilinguals showing advantages in different executive control tasks compared with low proficient bilinguals (Singh & Mishra, 2012, 2013, 2015, 2016). However, considering the current debate in the field, replication failures and other studies which totally deny any advantages, I remain sceptical. I review studies from both sides with the aim of seeing where the agreements and disagreements lie precisely. Of course, there have been allegations
of publication bias towards the studies showing an advantage. The various retrac-
tions and data abuses and failures in the area of social psychology are an example
(Pashler & Harris, 2012). This book attempts to look deep into these studies with an
open attitude as far as possible. Replication failures are frequent in many disciplines
and psychologists have been very cautious in recent times. The tone and tenor of
replication failures in the area of bilingualism and cognitive advantage have been
different in this regard. Here, peers have failed to see significant differences between
bilinguals and monolinguals on standardised cognitive psychological tasks.
However, my approach in talking about these studies and contextualising them has
not been to throw the baby out with the bath water. If many researchers have
observed advantage consistently, then it is important to see how and why they
achieved these results. Those who have replicated and did not gain the same answer
are also liable to answer questions regarding whether they had any flaws in their
methods and approaches, including participant selection. To examine this, I devote
an entire chapter (Chap. 4) to studies that have obtained null results.

1.1 The Bilingual Advantage Question

Bilingual minds and cognitive processes are fundamentally different from those of
monolinguals (Grosjean, 1989). Bilinguals speak two languages, and many are also
bi-literate. Often the bilinguals’ two languages come from two different cultures
(e.g. Chinese–English). Therefore, the semantic memory system of the bilingual is
a construct of two different cultures and interactions between them. Bilinguals
access words in each language with regard to their unique cultural attributes (Lee,
2002). This complexity affects bilingual language learning and lexical retrieval.
Over half a century of work with bilingual naming has demonstrated these effects.
Psycholinguists have been most interested in the question of language switching
and its cognitive impact. Simple object naming tasks have revealed intricate balance
and also failures (cost) when bilinguals produce words in both languages (Meuter &
Allport, 1999). These psycholinguistic processes have an important link to the ques-
tion of bilinguals’ cognitive control. Although the bilingual brain entertains two
representations unconsciously and simultaneously, it must also control them. This
control has been hypothesised to recruit executive functions such as inhibition
(Green, 1998). This book explores the nature of this control during language man-
agement in many of its chapters.

Because bilinguals know two languages, they need to select a language appropri-
ately and switch between the languages. Language control in bilinguals is an out-
come of such constant switching between two languages. Green’s original proposal
(Green, 1998) referred to a general purpose inhibitory control system that helps
bilinguals in their language selection. Since then, the debate has been around the
concept of inhibition. The question is whether bilinguals indeed inhibit the language
that they are currently not attending to or whether they a priori select one. This book
shows that apart from the inhibition model there are currently many other approaches
that emphasise attention disengagement, monitoring and also social contextual influences on the switching that contributes to language control (Valian, 2015). Most of these studies have used one of the other attention or executive control tasks to compare bilinguals and monolinguals. Researchers assume that tasks such as the Stroop or the Simon task capture the component of executive function that has been strengthened in bilinguals compared with monolinguals. At the heart of the issue lies finding the exact task that mimics what bilinguals do when they switch between languages.

What bilinguals do precisely as they fluently handle both languages is a question that has linguistic, neural and cognitive underpinnings. The classic object-naming task that reveals the switch cost in bilingual naming assumes inhibition of the non-target language (Meuter & Allport, 1999). Theories developed from such tasks point towards an inhibitory control account. However, as many other studies have shown, bilingual language control is context dependent. Bilinguals use the knowledge of their interlocutors to decide which language to use (e.g. Woumans et al., 2015). Such contextual awareness indicates a bilingual’s superior social cognition. This is something I have discussed in Chap. 2, which is on the evolution of bilingualism. Researchers are beginning to look at bilingual language control as a tussle between top-down control and bottom-up environmental forces. For example, the adaptive control hypothesis (Green & Abutalebi, 2013) and the bilingual ecology model (Green, 2011) deal with these issues. Therefore, bilingual language control in the real-world scenario could be very different than what is captured on laboratory tasks. We still don’t know how fluent bilinguals control their languages as they switch and shift between different interlocutors who speak different languages. Chapter 8 examines these social and contextual issues in an elaborate manner. The epicentre of the bilingual advantage debate lies in the interface of language control and performance on the executive control tasks. Thus, one can say the predominant framework is more cognitive psychological than linguistic, although the psychological and the linguistic interact in many of the tasks. Since the predominant style of investigation has focused on testing bilinguals on non-linguistic control tasks, I focus on these tasks more. Of course, there is a solid tradition of research that has explored how bilinguals and monolinguals process sentences in their first and second language, for example. In summary, in this book I attempt to sample some cutting-edge theories and data that researchers are currently pursuing in order to understand whether bilingualism bestows cognitive advantage. 

Valian (2015) comprehensively reviewed the bilingual advantage question. Apart from a literature survey, she pointed out a few important facts. She suggested that it is not clear which task actually may capture the mechanism of bilingual processing. I also think this way of looking at the scenario is justified since all tasks are based on certain specific assumptions. Unless the psycholinguistic processes that bilinguals use every day in different situations are clear to us, we can’t be certain which non-linguistic tasks will capture their modulator effects. If one assumes that bilinguals inhibit, then one thinks that the Stroop task is a good task to show this. However, there are multiple conjectures about the exact cognitive psychological processes at work when one is performing the Stroop task itself. Further, Valian also
wondered whether monolinguals with superior skills in some domains would perform just as well as bilinguals. In my commentary to that keynote article (Mishra, 2015), I suggested that bilingualism should be viewed as a skill and any benefits from it should be seen as an effect of its practice. Bilinguals who may have competence in two languages but do not use the two languages consistently may not benefit in terms of executive control. However, there are alternative views to this use-based theory.

As one read this book, you will notice a strange dichotomy between behavioural studies and neuroimaging studies. Do we assume that positive results from behavioural studies supporting our hypothesis should also be seen with neural data and vice versa? Most positive evidence has come from behavioural studies. Most replication failures also have used manual key press data to argue against the effect. Methods bring their own constraints to data interpretation and our theoretical understanding. It is possible that the subtle effects of bilingual advantages can’t be tracked by gross measures such as the reaction time-based studies. How do we then go about synchronising both neural and behavioural data? Recently, measurements using eye movements show that there are subtle differences between bilinguals and monolinguals in saccadic tasks (Singh & Mishra, 2012, 2015). These differences do not manifest in reaction time data. Interestingly, many brain imaging studies have consistently found evidence supporting the neural mechanism for bilingual advantage (e.g. Abutalebi et al., 2011). Unlike replication failures with behavioural data, there are few currently available with neural data. Whatever the reasons for this, this point can’t be overlooked when we are trying to generate a holistic understanding of the issues. I have devoted a separate chapter to the cognitive neuroscience of bilingual language control (Chap. 5). In addition, Chap. 7 discusses many eye tracking studies on attention and visual processing in bilinguals. The reason being, both positive and negative findings should be looked at when considering the methods and the specific assumptions behind them.

A serious lacuna can also be noticed in the diversity of bilinguals that have been studied. Most studies have come from well-known traditional bilingual areas such as the French-speaking part of Canada, Belgium, the Basque country, Luxemburg or parts of the USA. Researchers have not studied other cultures and bilinguals that may differ more widely on many measures. It is one thing to study Chinese–English bilinguals who are students in the UK and another to study such individuals in Beijing. The difference is obvious since both types of bilinguals live in different bilingual contexts. While one practises bilingualism within a largely monolingual environment (Chinese in Beijing), the other manages within a largely second-language context (in the UK). Therefore, randomly picking one group and studying them on executive control tasks may not reveal how their different environments have influenced their control. These issues were raised by Green (2011). Further, researchers often take participants whose first language may differ and create a homogeneous group. They are all bilinguals, but they are not similar types of bilinguals since their usage history may differ considerably. We cannot be sure that they have been practising bilingualism similarly unless we collect background data on this issue. In a recent article, Surrain & Luk (2017) reviews the classifying criteria
for bilinguals in a large number of studies and notes that there appears to be no unanimity. Different authors have used different sets of criteria with objective and subjective methods to evaluate language proficiency, and studies often do not present the language backgrounds of their participants. These issues make interpretation of results difficult. Recently, Anderson et al. (2018) developed a comprehensive language assessment questionnaire which takes usage context into account. I personally think that even if there is some advantage it is not to be found in all kinds of bilinguals. It is affected by a host of factors that include their language histories, the current level of practice and the cultures from which they come. Unfortunately, these factors will also confound the development of any general theory of bilingual language use and control.

I have written this book with the intention of narrating the state of the art without being an advocate for bilingual advantage. For the sake of clarity, I mention data and results that have supported the advantage theory and also the null results. The null results and replication failures are also discussed where they were not methodologically sound. The central question is: is there a bilingual advantage? Given the many null results and replication failures, many researchers now believe that there is no advantage as such. One can’t write a book today in cognitive psychology without giving special attention to the replication failures. Replication failures are common in different branches of science. Although psychologists have come under attack in recent times, this also applies to neuroscience (Button et al., 2013). Both direct and conceptual replications can fail for different reasons. Mishra, Hilchey, Singh, and Klein (2012) studied Hindi–English bilinguals using the Posner’s Cueing Task and took second-language proficiency as the grouping factor. Their rationale was that those bilinguals who have higher proficiency in the second language indulge more in bilingual conversations. They may also switch more often, and therefore their executive control system may get engaged more. They found that high-proficient Hindi–English bilinguals could disengage attention faster and thus displayed an early inhibition of return. Inhibition of return indicates the attention system’s inability to move to a previously attended location. The authors proposed that bilinguals may be good at disengaging attention faster and this could be linked to bilingualism. Later, Bialystok and colleagues (Chung-Fat-Yim, Sorge, & Bialystok, 2017; Grundy, Chung-Fat-Yim, Friesen, Mak, & Bialystok, 2017) using other tasks also have proposed similar theories of attention, disengagement and bilingualism. More recently, Saint-Aubin et al. (in press) failed to replicate Mishra et al.’s work in Moncton, New Brunswick, Canada. Moncton is French-speaking and has many bilinguals with English as their second language. The idea of their study was to see if the findings from Mishra et al. could be replicated in the Canadian context. The results showed that bilingualism did not explain performance on the cueing task. It is quite possible that cultural and contextual differences may explain this non-replication. Importantly, such cross-cultural replication is the need of the hour as replication failures raise many more new questions than they answer. I have devoted an entire chapter addressing this issue (Chap. 4).

More recently, the question of bilingualism and advantage has been looked at from a global socio-political perspective. Does bilingualism lead to a lower
incidence of adult neurological diseases in different countries? Klein, Christie, and Parkvall (2016) took the incidence rate for Alzheimer’s disease from 93 countries and then plotted the number of bilinguals and monolinguals in each country and correlated this with the incidence rate. When the mean number of languages was correlated with the percentage of people with Alzheimer’s in each country, the results indicated that the number of languages spoken in the country grew as the incidence of AD decreased. This was a first of its kind report which applied a statistical approach to publicly available data to see if bilingualism has any effect on life expectancy and cognitive reserve at a mass level. Of course, the limitations of such a method was acknowledged by the authors. But this approach opens up the possibility to examine the bilingualism hypothesis at a very large scale in many countries. In Chap. 8, I stretch this theme to also include the possible connections between bilingualism and social issues such as conflict management. At present, large-scale datasets are not available, although much can be done in this direction. Issues may include understanding and promoting bilingualism at schools, such as the dual immersion programmes in many countries (e.g. the USA) and their possible impact.

There have also been recent attempts to connect the practice of bilingualism to national and global policies on education, culture and conflict management. Geopolitical forces have led to dynamic shifts in the world order and societies, which are more evident now than before. For example, after the UK’s decision to move out of the European Union (EU), many scholars are wondering what impact it may have on language policy in the UK and more widely in the EU. Many researchers are speculating about what the language landscape of the UK will look like after it cuts tie with EU (Kelly, 2017). Situations like these offer new possibilities for researchers to test hypotheses regarding bilingualism and its connection to cognition and culture at a broader level. The EU, a political and economic organisation consisting of many European countries, emphasises the use of most European languages and also English in different countries. In a recent book on the issue of Brexit’s impact on language policy and planning in the UK, the authors reflect on the many issues that could emerge after the Brexit (Kelly, 2017). Mehmedbegovic (2017) proposed that bilingualism is necessary for the success of policy in a multicultural world. Such writings indicate a growing interest in bilingualism and its benefits to policy makers. If Brexit leads to fewer multilinguals as a result of fewer immigrants, then this may also lead to a higher incidence of dementia. Such situations may impact economics and trade adversely (Hogan-Brun, 2018). It may just be speculation, but given the study by Klein and colleagues (2016), one can think in this direction. Bilingualism not only enhances one’s chances of employability but also strengthens cultural assimilation. More and more multinational companies that operate globally are looking for a workforce that knows more languages. In this age of constant and persistent armed forces deployment at many locations in the world for maintenance of world peace, the people on the ground must speak two or more languages. The key question that is emerging now from recent political events around the world is whether the rise of nationalism in many countries and shifts in
power will lead to a decrease in bilingualism or multilingualism? The study of bilingualism and cognition can’t stay away from such important questions.

1.2 The Components of Control

Chapter 3 covers the most important theoretical issues that are being implicated currently in addressing the bilingualism–cognitive advantage debate. Soon after Green (1998) proposed his inhibitory control theory, which linked bilingual language control to a domain-general executive control, many researchers sought evidence in tasks such as the Stroop or Simon tasks. The assumption was that bilinguals must inhibit an inappropriate language by applying executive control and selecting the correct one. Constant practice of this mechanism must enhance inhibitory control.

Today, many researchers have started to focus on mechanisms such as selective attention, flexibility in switching, monitoring and goal maintenance. At the same time, theories of executive control in human cognition and performance are being re-examined (Miyake et al., 2000). In this book, I have suggested that all this rests on our assumption of what exactly bilinguals do in order to achieve flawless language control. Whatever mechanisms we assume to be the cause will guide us towards an appropriate non-linguistic task that measures it.

For any mechanism that is proposed to be linked to executive control, results have been mixed. Let us consider the case of language switching—a very common feature of bilingualism. However, the frequency of switching differs across bilinguals’ cultures. Importantly, we assume that switching involves a cognitive cost. Researchers think that linguistic and non-linguistic switching should correlate in bilinguals. For example, Prior and Gollan (2011) found that Spanish–English and Mandarin–English bilinguals who switch more do well on executive control tasks. Similarly, Verreyt, Woumans, Vandelanotte, Szmalec, and Duyck (2016) found that Dutch–French bilinguals in Belgium who switch more show higher executive control. However, Paap and Greenberg (2013), who examined many bilinguals with different types of language pairs, did not find any correlation between frequency of switching and executive control advantage.

Most studies that have examined switching have used the cued object naming task. How about switching when it is voluntary? Gollan and Ferreira (2009) examined voluntary switching by asking speakers to name objects. They could use any language to name but should maintain a balance between the choices. This certainly led to some top-down constraint on language selection. Nevertheless, the bilinguals switched only 25% of the time. Switching is cognitively costly and hence is not preferred. The frequency of switching could be linked to proficiency (Costa & Santesteban, 2004). Highly proficient speakers also switch a lot. Most research interest has been in understanding the effect of switching and whether the general purpose executive control system governs switching. However, others report that if the speakers are ideally balanced then such a switch cost is not seen. Gollan and Ferreira asked younger and older Spanish–English bilinguals to either name objects
with their dominant language, less dominant language or mix languages as they liked. Balanced bilinguals mixed languages even when they paid a switch cost. Importantly, when free mixing was allowed, the less balanced bilinguals performed the same as the balanced bilinguals. Further, when speakers switched voluntarily, their naming was facilitated. This means that the freedom to choose one’s language leads to better performance.

Bilinguals also switch along with their interlocutors. This social angle to the question of switching has provided novel insights. Gambi and Hartsuiker (2016) created a situation where one participant switched voluntarily between the two languages. The speaker was asked to name pictures in blocks. It was observed that speakers were slow in naming objects in a language which was not earlier used by the switching participant. This means speakers were trying to accommodate the switching internally as they were planning their language. This bottom-up influence on language selection suggests that switching is not always top-down. Pickering and colleagues (Pickering & Garrod, 2004) have shown that during such joint actions, participants try to synchronise their actions. This has also been seen in other joint action tasks. In one experiment, Dolk et al. (2013) showed that participants paid a higher cost in a Simon task when a Chinese cat kept constantly and randomly waving its hands. Participants tried to synchronise their actions with the cat. Such examples suggest the contagious nature of joint actions, and language switching is no different.

Bilinguals also constantly monitor their environment to select the appropriate language for a particular interlocutor (this is discussed at length in Chap. 6). Many current studies show that bilinguals are sensitive towards their interlocutors and select their language (Bhatia, Sake, Prasad, & Mishra, 2017; Li, Yang, Scherf, & Li, 2013; Woumans et al., 2015). This sensitivity towards potential interlocutors in the environment cannot arise without good monitoring. When it comes to language and bilingual use, monitoring includes the management of two languages. Monitoring can also include managing two tasks or occasional conflicts. Since interlocutors can change dynamically in the social setting, how do bilinguals control their language in such a situation? Monitoring also involves detecting conflict in order to reduce the cognitive cost. Conflict can arise when one can’t be certain about an interlocutor’s languages. Neuroimaging studies show that the anterior cingulate cortex (ACC) shows higher activity during error monitoring and even when one competes with multiple responses (Carter et al., 1998). Detecting conflict and preparing the appropriate response is central to cognitive systems (Botvinick, Barch, Carter, & Cohen, 2001). Therefore, monitoring is central to both managing conflict and also to ensuring fewer errors. Monitoring suffers in a range of psychiatric and neurological conditions (Charles et al., 2017; Taylor, Fitzgerald, & Abelson, 2016); however, the ability to monitor and minimise conflict improves with experience. For example, it has been shown that with higher interpreting experience, monitoring ability also increases (Dong & Zhong, 2017). But it should be noted that suggesting monitoring as a key mechanism for bilingual language control does not mean that inhibitory control is not useful.
The term ‘cognitive flexibility’ these days is used commonly to indicate fluent behaviour achieved through practice. Flexibility also includes the ability to maintain conflicting information in the working memory to be ready to use when demanded. This idea conflicts directly with the ‘strong inhibition’ theory of an inappropriate response. If a response is inhibited in this trial because it is not task-appropriate and if the same response becomes relevant on an upcoming trial, how does one retrieve it? Bilinguals have to constantly switch flexibly between their languages as any language may become relevant next. Does bilingualism bestow cognitive flexibility? Bilingual children apparently show cognitive flexibility in drawing objects at an early age (Adi-Japha, Berberich-Artzi, & Libnawi, 2010); that is, when asked to draw objects that do not exist, their drawings show a kind of flexible blending of features unique to those objects. Neuroimaging evidence suggests that the ACC modulates cognitive flexibility in bilinguals distinctively compared with monolinguals when they attempt novel tasks (Becker, Prat, & Stocco, 2016). Bilinguals can also flexibly shift between stimulus–response mapping during task switching (Wiseheart, Viswanathan, & Bialystok, 2016). These pieces of evidence suggest that bilingualism configures the neural networks differently, giving an edge to bilinguals in mental flexibility on linguistic and non-linguistic tasks.

Thus, be it switching, monitoring or deployment of selective attention, they are all functionally linked at an underlying level. Further, recent research has also indicated the influence of bilingualism on working memory (Bialystok, Poarch, Luo, & Craik, 2014). If we can find tasks that capture that very cognitive system which has been enhanced by bilingualism, it will be fantastic. However, tasks are simplified constructs that each have their own impurity. For example, it is very difficult to say whether inhibition, selective attention or monitoring is involved in the Stroop task. At this point in time, psycholinguistic studies into language control using switching as a model have revealed many insights. The effect of individual difference factors and context is being explored by current researchers. This book aspires to provide a synthesis of these diverse theories and facts.

### 1.3 Structure of the Book

Chapter 2 explores the evolutionary underpinnings of bilingualism. Disciplines such as cognitive archaeology are now contributing on the issue of the evolution of human cognitive capacities in both spatial and temporal terms. The key question is whether the capacity to be bilingual emerged at a certain point in our evolutionary history. Work on the evolution of language has been very divisive, and different people have proposed diverse theories (Berwick & Chomsky, 2015; Tattersall, 2016). However, there has been very little theorising on the evolution of bilingualism. The chapter also explores the evolution of social cognitive abilities in humans that might have made bilingualism possible. In order to understand the cognitive capacities that are influenced by bilingualism, it is important also to consider which capacities in the history of our evolution were crucial to accommodate bilingualism.
in the brain. Crucial cognitive skills such as monitoring, switching, shifting and inhibiting are early capacities to emerge in our history. The same capacities are also used in many non-linguistic operations. The chapter attempts to synthesise data from multiple domains to suggest that evolutionary psychological theories can better inform us about bilingualism and its relation to the brain.

Chapter 3 is about the conceptual constructs on which the bilingual advantage debate is based. Without knowing the psycholinguistics of bilingualism well, it is not easy to link general cognitive advantage with language control. Researchers try to administer tasks that they think mimics a certain linguistic or non-linguistic operation. For example, the chapter discusses translation, inhibition, monitoring, switching and social attention. These are the core mechanisms that different researchers have implicated for cognitive advantage. Once these mechanisms are defined, then it is possible to develop causal models of cognitive control. Whether bilinguals inhibit or select a language more efficiently is a matter of how one conceptualises the mechanism. The chapter provides a preview to the later chapters where these concepts reappear more frequently.

Chapter 4 discusses the replication failures that have led to newer questions and controversies. Beyond the facts, I also discuss many metascientific issues related to replications and their interpretation. Based on their failed efforts, many authors have called for the field to abandon its investigation of cognitive advantage and move on (Goldsmith & Morton, 2018). I argue that this may not be the right approach as of yet as null results should encourage us to explore alternative explanations. It is very important to find out whether some bilinguals show no advantage at all. If bilinguals do not practice their two languages with other bilinguals continuously there is no challenge for the brain and there is possibly no cognitive advantage. Given this, it is possible that studies that have obtained null results have considered bilinguals who may have less practice of bilingualism. Merely including participants who say that they know two languages is not enough to expect advantage if compared against monolinguals. Further, methodological diversity across studies make it difficult to arrive at a coherent theory.

Chapter 5 focuses on the bilingual brain. Neural data tells how bilingualism sculpts the neural structures since infancy. Many recent studies show that bilinguals use key neural structures such as the ACC to monitor conflict. Abutalebi et al. (2011) proposed that the ACC actually could have evolved to serve bilingual conflict. A conflict could relate to the selection of the correct language and also with interlocutors. The adaptive control hypothesis (Green & Abutalebi, 2013) essentially links neural responses to contextual constraints in bilingual language selection and control. Many studies that have used the EEG methodology have revealed how bilinguals plan and process language. Insights from the brain mechanisms could cast new light on the biological basis of language. Importantly, these areas have been found to be active for both linguistic and non-linguistic conflict tasks. I discuss the neural basis of second-language processing and also how bilingual brains react differently to conflict and attention tasks. There is an emerging consensus that bilingual and monolingual brains are essentially similar structurally; however, they differ with regard to functional connectivity during tasks. This functional
connectivity helps bilinguals to sort conflict and remain focused on communicative goals. However, some studies have shown that bilinguals may have higher white matter density than monolinguals (Anderson et al., 2017). As I have maintained throughout, many of these neuroimaging studies show bilingual advantage, which is often not translated into behavioural results. The key issue now is how to integrate neural and behavioural findings towards a holistic theory of bilingual language processing, control and cognition. Refinements in behavioural methods and our understanding of the tasks as well as increasing sophistication in neuroimaging techniques should reveal how bilingualism changes both structural and functional connections of the brain early on.

Chapter 6 discusses the influence of context on bilingual language and cognitive processing. It emphasises that bilingual control should be explored with regard to real communicative scenarios. How is control exercised in the face of diverse interlocutors? Green and Abutalebi (2013) proposed the adaptive control hypothesis, which links language selection to environmental stimuli. The critical question is how bilinguals select their languages in a social setting where there are interlocutors. Each interlocutor is identified as having competence with two languages. At times, however, proficiency in these languages may differ a lot. Thus, in a social setting, the challenge for the bilingual speaker is to choose the appropriate language for the interlocutor. These selections can be dynamic as interlocutors may replace one another. Therefore, any model of bilingual language selection and control has to take into account these variables. In Chap. 2, I make the point that the evolution of social cognition in Homo sapiens has been the most important thing in our evolutionary history. The bilingual’s ability to infer from interlocutors’ faces which language to use is a good example of such sophisticated social cognitive skills. Current research (Blanco-Elorrieta & Pylkkänen, 2017; Molnar, Ibáñez-Molina, & Carreiras, 2015; Woumans et al., 2015) suggests that bilinguals are very good at predicting the language of the interlocutor with a slight visual glance. These data have enriched our understanding of how bilingualism aids in social cognition and communication.

Most researchers agree that attention plays a key role in goal-directed action. Among the many cognitive mechanisms that bilingualism researchers have explored, attention appears to be central. Chapter 7 focuses on attention, vision and language in bilingual cognitive processing. Attention has been now hailed as the mechanism which can explain how bilingualism may modulate neural structures and cognitive performance. Attention, of course, is widely studied within cognitive psychology and cognitive neuroscience. Many tasks are regularly employed in measuring the movement of attention in the spatial domain as well as the effect of deploying attention. Visual world eye-tracking data have shown language non-selective attention in bilinguals. Similarly, studies have shown a difference between bilinguals and monolinguals on attention tasks. Most recently, Bialystok (2017) has suggested that bilingualism may modulate selective attention. In Chap. 7, I discuss both linguistic and non-linguistic aspects of attention control in bilinguals. I also discuss many visual world eye-tracking studies that show how linguistic processing influences attention. This chapter aims to offer a thorough up-to-date account of how attention has been
used as a mechanism to explain both language processing and cognitive control in bilinguals.

Chapter 8 provides a lengthy summary of the main themes discussed in the book and future perspectives. The chapter emphasises that abandoning the research question is not a viable idea, but that efforts must be made to sharpen the hypothesis, much like the search for dark matter in cosmology (de Grasse Tyson, 2017). We often see that some people are cognitively much smarter than others. It is also the case that sometimes these people are bilinguals. Thus, the key linking hypothesis between superior cognitive performance in different unrelated tasks and bilingualism is not an unreasonable hypothesis. We know other complex skills such as music and even sport strengthen the neural structure bestowing cognitive advantage (Babiloni et al., 2010; Gaser & Schlaug, 2003). In Chap. 8, I suggest that a complete cognitive exploration of bilingualism with regard to the brain and the mind has to take context and actual language use very seriously. I also discuss possibilities for expanding the domain of research considering changes we see today around the world. Massive immigration of people because of social upheavals and rising nationalism in many countries that do not promote multiculturalism offers unique possibilities to study the impact of bilingualism. What happens when refugees struggle to learn the language of the host? Cognitive control studies should now move out of laboratories and into social settings. I cite studies that show that this is being addressed by researchers in many other disciplines such as socio-linguistics and culture studies. I also ask the big question: how does the executive control of bilinguals help achieve conflict resolution in wider social issues? Of course, at this point these ideas are only speculative.

1.4 Summary

Whether there is an advantage in bilingualism or not rests on the understanding of several variables, which could be cultural, socio-economic, linguistic, emotional and also pedagogical. Neuroplasticity as a result of bilingualism leading to a visible advantage cannot happen alone but rather in consonance with many of these other variables. Therefore, the hunt to find the effects on cognition that are uniquely as a function of practising two languages could be problematic. Socio-economic and cultural factors differ very much across countries. Bilinguals in the USA are not similar to bilinguals in Belgium or India. Therefore, if findings are not replicated, the reasons could lie in such factors. Official policy and language teaching and learning environments may differ a lot. The community support for bilingualism in an area influences the quantum of practice and to what extent young language learners use the second language. Therefore, it is not easy to isolate only the effect of bilingualism and examine it in an experimental context. Much research in the fields of cultural and socio-psychology demonstrates how pervasive these variables that researchers often find very hard to integrate into experiments may be. Researchers indeed have questioned whether socio-economic factors underlie the effects one
sees in such experiments. I did not intend this book to be just a way to take stock of what we know so far relating to the advantage issue. Apart from this, the book also delves into newer questions such as that of context and socio-political forces that shape bilingualism across the world. I show that there is a gap between behavioural and neuroimaging findings. The chapter on replications shows how these studies can also be questioned on methodological grounds. Currently, the whole of psychological sciences is being scrutinised a great deal. However, neuroplasticity induced by the extreme and continuous practice of any skill is also a fact. The book attempts to take a bi-partisan stand on this issue, looking at the evidence available so far. The question of bilingualism is very important since it demonstrates the enormous ability of the human brain to be accommodating and the social skills that are critically important, now more than ever before.

References


References


Chapter 2
The Evolution of Bilingualism

2.1 Introduction

Bilingualism is defined as the fluent and voluntary use of two languages. The great geneticist Theodosius Dobzhansky said that nothing in biology makes sense except in light of evolution. How did bilingualism evolve in our species? Was it selected by natural selection since it offered cognitive, neural and social benefits? Or did it evolve as the next logical thing out of social and cultural pressure after our ancestors had their languages and a good amount of social skills were in place? Should the debate exploring the evolution of bilingualism wait until one settles how first-language capacity emerged?

Debates on language evolution were banned by the Société de Linguistique de Paris in 1866 (Harris, 1988)—at that time, everybody agreed that the question was intractable, and no energy should be spent on it. However, the study of language evolution is now a well-developed field (Fitch, 2016; Oller, Dale, & Griebel, 2016). Now and then one finds a new book provoking a newer hypothesis on the evolution of language (Botha, 2016; Berwick & Chomsky, 2017). However, it is still not clear if the evolution of language was cultural or biological and we know little about origins of bilingualism. In a recent special issue of Topics in Cognitive Sciences (Oller et al., 2016) there was not a single article on the evolution of bilingualism. Similarly, in their ambitious work on language evolution, Berwick and Chomsky (2017) write little on bilingualism. Probably many have assumed that there is nothing special about bilingualism as far as its evolution is concerned. Some proposals on the evolution of bilingualism (Roberts, 2013) consider bilingualism to be older than monolingualism. In this chapter, I examine debates in language evolution, paleoanthropology and social cognition to trace the evolution of skills that led to bilingualism. If it is important to know the cognitive consequences of bilingualism, it is also important to examine how it has evolved. Lack of a fossil record and a comparative species to look into for answers has led to no clear hypothesis on the evolution of bilingualism. There is no evidence of any other species using two
communication systems at will. Bilingualism uses core computational and neural mechanisms, including heightened social cognitive skills, which humans possess. We need a neural and social evolutionary theory of bilingualism as a complex mental skill.

An inquiry into the evolution of bilingualism is an inquiry into the evolution of those core cognitive systems that make bilingualism possible in the brain—in particular, the ability of the brain to manage two languages at will and negotiate many social and cultural contexts using executive control. The brain uses sophisticated forms of conflict management and monitoring in managing two languages (Green, 1998; Kroll & Bialystok, 2013). The following appear to be possible contributing factors to the evolution of bilingualism. Many of these ideas will be elaborated later.

(a) Learning and exchanges in two languages were possible when *Homo sapiens* developed sophisticated social cognition that enhanced their theory of mind and intentionality (Corballis, 2016).

(b) The brain’s ability to monitor, switch and shift at will and inhibit responses with regard to context.

(c) Emergence of the executive control system that includes working memory and selective attention.

(d) Social and cultural evolution (Sterelny, 2016).

It is also possible that bilingualism developed as our ancestors left Africa and interacted with others on their way to different continents. Even if they met, however, why did learning one another’s language appeared significant and which neural and cognitive systems supported such an endeavour? A science writer in *The Guardian* wrote that “Language evolution can be compared to biological evolution, but whereas genetic change is driven by environmental pressures, languages change and develop through social pressures. Over time, different groups of early humans would have found themselves speaking different languages. Then, to communicate with other groups – for trade, travel and so on – it would have been necessary for some members of a family or band to speak other tongues.” (Gaia Vince, “Why being bilingual works wonders for your brain?”, Aug 2016) Data from human evolution and migration studies suggest that once out of Africa, our ancestors did make it to other continents, meeting and interacting with other early hominins who were different than them (Walter et al., 2000). For example, apart from the *Homo sapiens* in Eastern Africa, there were the Neanderthals in Northern Europe, the *Homo erectus* and the Denisovans in China (Korisettar, 2016). If these different hominins met and they had a language (communication system) of some sort, then this was the beginning of bilingualism. Many believe that no other early hominin had similar or competing cognitive abilities like *Homo sapiens*. Then two groups of speakers with distinct languages and brains capable of social cognition tracking one another’s intentionality (Oesch & Dunbar, 2016) met, bilingualism may have emerged. However, a dominant view in contemporary studies of language evolution states that no other early hominins had any form of language than the *Homo sapiens* (Tattersall, 2016). This means that although there was a social interaction between these different species, there was no linguistic interaction. Nevertheless, such interactions did
enrich the neural systems supporting social cognition, which perhaps later came handy for bilingualism.

Why was the phenotype for bilingualism selected by evolution? Bilingualism might well have evolved to keep early hominins cognitively fit. Gaia Vince, the writer I previously quoted, also suggested that “Such results suggest bilingualism helps keep us mentally fit. It may even be an advantage that evolution has positively selected in our brains, an idea supported by the ease with which we learn new languages and flip between them and by the pervasiveness of bilingualism throughout world history. Just as we need to do physical exercise to maintain the health of bodies that evolved for a physically active hunter-gatherer lifestyle, perhaps we ought to start doing more cognitive exercises to maintain our mental health, especially if we only speak one language.” It’s certainly a provocative hypothesis that natural selection preferred bilingualism since it offered cognitive advantage and also protection against serious brain diseases. Much recent research has suggested that long-term practice of bilingualism protects the brain better against Alzheimer’s disease (Craik, Bialystok, & Freedman, 2010). Current research on older bilinguals shows that they have superior cognitive reserve (Bialystok, Craik, & Freedman, 2007; Woumans, Santens et al., 2015). Cognitive reserve is the brain’s immunity against terrible neurodegenerative diseases. We can assume that since using two languages offered cognitive, neural and social benefit, brains evolved to permanently adopt its use.

The evolution of material and complex symbolic culture made brains entertain new challenges. The complexity of material culture and need to socially cooperate probably led to the evolution of linguistic communication Deacon (2016). Thus, as the population grew and society became complex, individual brains had to be observant of others. Kim Sterelny, in his book The Evolved Apprentice (Sterelny, 2012) proposed that the human mind arose in cooperation. When early hominines learned to cooperate, they also influenced how they lived and thought—including transferring these skills to the next generation. Abilities such as conflict monitoring and goal maintenance must have come about through group interaction at such times. If humans had stayed solitary, then most of these abilities would not have evolved. Even in the context of bilingualism, speakers and listeners have to constantly keep track of others’ intentions and speech plans. Thus, social cooperation and its cognitive demands must have helped maintain communication with others. Hominins learned to work together and produce complex objects that became part of their cognitive heritage. While one set of cognitive abilities might have been necessary to produce complex tools and artefacts, once mass produced with others, they in turn also influenced the emergence of newer cognitive skills. These skills had direct interface with social cooperation and language emergence. Since bilingualism had to be practised with others like a game, a complex maze of a socially supportive structure was necessary. Merlin Donald wrote “Language is, in this sense, not a feature of the brain per se. It is a cognitive epiphenomenon, a socially constructed (Searle, 1969) cultural over-write imposed on a brain which is essentially primate in its design. Language thus has its origin in a distributed cognitive system, while it is performed by a local cognitive system, that is, the brain of an individual. It is the child of an interactive cultural imagination, that is, of groups of brains in collision.”
No doubt, social and cultural forces shaped the evolution of brain networks that later adapted to newer challenges. The brain’s ability to support bilingualism was one such important milestone.

### 2.2 Emergence of Language: Mutation Versus Gradual?

While the evolution of *Homo sapiens* from primates is not disputed, many have taken the view that this important symbolic behaviour could be of accidental emergence—because of a mutation (Hauser, Chomsky, & Fitch, 2002). Others hold the developmental, gradualist and evolutionary view (Lieberman, 2016). Was there a sophisticated neurocognitive machinery in place already before language emerged? Chomsky has long held the view (without much material evidence to support the claims) that the question is not about the evolution of a communication system but the emergence of a sophisticated computational apparatus for symbolic thought (Berwick & Chomsky, 2017). This has nothing to do with communication and articulation; therefore, the social, cognitive and evolutionary angles are redundant. This computational capacity for symbolic behaviour emerged as a sudden mutation in a select group of *Homo sapiens* (Berwick & Chomsky, 2017; Bolhuis, Tattersall, Chomsky, & Berwick, 2015). This was without any evolutionary precedence—without any trace of gradual development.

Chomsky and colleagues propose that the core computational capacity supporting language emerged some 60,000–80,000 years ago. This is after 2 million years of anatomically modern humans’ (*Homo sapiens*) emergence on Earth. Formalists like Chomsky do not appeal to domain-general cognitive or neural capacities but assume them to be important for hosting the algorithmic structures that lead to symbolic computation necessary for language activity. ‘Merge’ means to blend two different structures and make a different one. This is the essence of language and thought according to Chomsky. Unless the algorithm did merge, the combinatorial and recursive aspects of language could not be realised. Figure 2.1 shows a schematic description of ‘merge’ in the Chomskyian framework. The system in place takes any two fragments and applies some rules and blends them together, producing

![Fig. 2.1](image.png)

*Fig. 2.1* The mechanism of ‘merge’ as per Chomsky’s system. A sentence is expressed as a collection of phrases. Each phrase is headed by a lexical word. The individual nodes are smaller fragments of language. These fragments need to be combined to form large sentence-like units. Phrase structure rules operate on similar structures
longer phrases. This procedure further goes on and on recursively. This had nothing to do with oral language or the existence of the vocal apparatus or neural structures in the hominids to support such an ability. No other early hominoids, even if they were contemporaries of our ancestors, had this ability; therefore, their brains could not configure complex symbolic structures. Within linguistics, others have offered a functionalist and gradualist account of language evolution (Jackendoff, 2012; Newmeyer, 2016). A functionalist account focuses on the cognitive and cultural aspects of language evolution more than the formal structures that define linguistic symbolic structures. In the absence of a verifiable fossil record or archaeological proxies, we do not know when the language faculty and computational apparatus evolved.

Ian Tattersall, a well-known paleo-anthropologist, while reviewing Chomsky’s book (Berwick & Chomsky, 2017) observed that if you leave the writing systems, it is tough to say anything about the evolution of human language in any objective manner (Tattersall, 2016). There is simply no evidence that can point towards a particular timeframe when hominids began speaking using syntax. Tattersall (2014) also rejects the various proxies such as archaeological artefacts and handmade stone weapons that archaeologists bring to argue for the position that such *Homo sapiens* did have a sophisticated cognitive system which was conducive for language evolution. Therefore, the proposal that ‘merge’ was an outcome of a genetic mutation has to be accepted without corresponding physical evidence. No evidence from increased skull size or head dimension in modern humans will be sufficient to endorse the fact that they indeed gave rise to a symbolic capacity. Bolhuis et al. (2015) wrote that “Questions of evolution or function are fundamentally different from those relating to the mechanism, so evolution can never “explain” mechanisms. For a start, the evolution of a particular trait may have proceeded in different ways, such as via common descent, convergence, or exaptation, and it is not easy to establish which of these possibilities (or combination of them) is relevant. More importantly, evolution by natural selection is not a causal factor of either cognitive or neural mechanisms. Natural selection can be seen as one causal factor for the historical process of evolutionary change, but that is merely stating the essence of the theory of evolution.” Is this acceptable to others who are still searching for fossil evidence to account for language evolution?

Explaining a random mutation that created at once a powerful computational mechanism such as ‘merge’ may seem problematic evolutionarily. Supporting the evolutionary–incremental view, Lieberman (2016) wrote that “Humans are the only living species that possesses language, but its evolution does not appear to involve any singular evolutionary mechanism that is in any sense unique to human. The evolution of human language hinges on natural selection acting on heritable biological variation.” Lieberman believes that the evolution of human language is not an outcome of any specific evolutionary process unique to humans. Further, he states that evolutionary processes that are specific to humans shaped language and no brain mechanisms appear to be specific to speech or language. A full appraisal of the biological bases of human language remains in the distant future. Lieberman also proposes that most brain structures that today subserve language and higher
cognition are “recycled”. Does this mean that these structures developed to serve other core functions but later forces of natural selection adopted them for language? With regard to brain areas, those such as the frontal and parietal areas and the visual cortex were probably present even in most archaic humans (Fig. 2.2) when they had no language. Following this logic, most brain areas that are implicated for bilingualism, such as the anterior cingulate cortex (ACC) and other attentional areas, were present much before language arose.

Others have argued that we must look at gestures and their evolution as a precursor to language (Goldin-Meadow, 2016). Even current work with bimodal bilinguals has shown some of the core mechanisms to bilingualism such as shifting, switching and parallel language activations are similar across modalities (Emmorey, Luk, Pyers, & Bialystok, 2008). Some have suggested that cultural evolution shaped how brains evolved and therein the various cognitive abilities (Morgan et al., 2015; Thompson, Kirby, & Smith, 2016). In Sect. 2.3 I look at cognitive archaeology with the hope of finding proxies that may indicate the emergence of cognitive systems that probably supported the seamless manipulation required for the practice of bilingualism.

2.3 Archaeological Proxies and the Evolution of Complex Cognition

Bilingualism is an instance of complex cognition that calls for both contextual sensitivity and control. When did complex cognition in hominins emerge? Probably the first cognitively radical transformation in our early ancestors happened when they stood erect and walked with hind limbs. This led to several changes both cognitively
2.3 Archaeological Proxies and the Evolution of Complex Cognition

and otherwise. Figure 2.3 shows early *Australopithecus afarensis* footprints discovered by Mary Leakey and others in 1975. This evidence has been taken as the first suggesting bipedalism in our earliest ancestors. When early hominins could walk on two legs, their hands became free for more complex actions. The emergence of bipedalism has been considered one of the earliest landmarks in the evolution of hominoid cognition (Donald, 1991). When the forelimbs were free, they could be used for more fine and complex actions such as tool and weapon making or maybe even art. The footprints found at Laetoli, Tanzania have been dated to be 3.5 million years old. Anatomically modern *Homo sapiens* evolved around 2 million years ago. According to current estimates, language evolved around 60–80,000 years ago (Berwick & Chomsky, 2017). Bipedalism must have led to extensive use of hand gestures for communication as hands became free. And we all know what role gestures might have played in the subsequent evolution of human language (Corballis, 1999).

Similarly, substantial structural modifications in the hominin brain led to the emergence of complex cognition. Although the development of cranial capacity and expansion of frontal lobes in *Homo sapiens* is a very popular theory to account for our intriguing mental skills (Wynn & Coolidge, 2017), recently much more interesting proposals have emerged. The internal carotid arteries supply blood to the human skull. Seymour, Bosiocic, and Snelling (2016) propose that more than brain size, the dimension of these arteries increased significantly in *Homo sapiens* leading to greater blood flow to support a high metabolism rate (Fig. 2.4). This makes sense since most studies in brain imaging research measure the volume of blood flow to the brain and different areas during demanding cognitive activity. Thus, bipedalism and brain modification allowed *Homo sapiens* to execute tasks that called for complex thinking, computation as well as control. As for language, gestures emerged as key companions to communication.

Modern *Homo sapiens* were one of the early hominins who apparently developed a distinctive frontal lobe and greater cognitive abilities (Tattersall, 2014). Figure 2.5 shows the many subspecies of hominins that preceded the *Homo sapiens*. The Neanderthals were one of these subspecies and have been studied a lot from different perspectives with fossil records. One of the most intriguing questions has been whether Neanderthals had any language. While the Neanderthals may have had some capacity for speech (Le May, 1975), it was not suitable for the complex
Fig. 2.4 Increase in internal carotid in *Homo sapiens* compared with other early hominins. (Seymour et al., 2016)

Mya

0 1 2 3 4 5 6 7


Mya

0 1 2 3 4 5 6 7

Fig. 2.5 Time course of human evolution: modern *Homo sapiens*. (Tattersall, 2014)
manoeuvring which human speech requires. How nuanced it was is open to discussion. Neanderthals’ incapacity for complex speech might have led to their ultimate demise (Lieberman, 1992). The Neanderthals did not develop much social cognition as a result of their separate evolutionary track compared with modern humans. Pearce, Stringer, and Dunbar (2013) suggest that the Neanderthals’ brain developed a superior capacity for visual cognition as they had much larger occipital lobes, whereas the modern humans developed a bigger parietal and frontal lobe and with it came superior social cognition. Gunz, Neubauer, Maureille, and Hublin (2010) suggested that Neanderthal infants had a similar cranial capacity at birth to modern Homo sapiens infants, but during development, the brain of Homo sapiens became more globular while for Neanderthals it did not. Further, for Homo sapiens the frontal region developed remarkably while for Neanderthals development was restricted to the posterior of the brain. The emergence of symbolism indicating sophisticated cognitive ability is fundamental in understanding how language, art, mathematics and music might have evolved. Current evidence suggests that Neanderthals could make symbolically rich jewellery long before anatomically modern humans populated Europe (Finlayson et al., 2012). Such Neanderthal jewellery made from animal tooth and bones may suggest not just a sense of aesthetics but also cognitive and motor skills; however, more complex symbolism emerged around 50,000 years ago with modern Homo sapiens (Rossano, 2010).

Others have proposed that the Neanderthals had the modern human’s capacity for speech and language including some syntax (Dediu & Levinson, 2013). This capacity must have allowed them to interact with modern humans. Neanderthals and modern humans did have an interaction for an extended period before their disappearance. However, it is not clear if Neanderthals’ speech capacity allowed them to interact profitably with modern humans. Dediu and Levinson (2013) even suggest that the current language diversity can be seen as coming from these two distinct evolutionary sources. The African languages may have come from modern humans and the European languages from the Neanderthals. Did this period of interaction set the first precursor to bilingualism? Both Neanderthal and modern humans must have tried to learn one another’s communication system. However, in the absence of solid evidence, this remains a conjecture at best. Berwick, Hauser, and Tattersall (2013), commenting on the proposal of Dediu and Levinson (2013), wrote that “Our language phenotype is a competence consisting of three systems—syntax, semantics, and phonology—that are internal to the mind/brain, along with two mediating interfaces, the first linking the representational/computational systems to external speech or sign, the second linking language to internal thought. The internal combinatorial computations are generative and rule-governed, engaging representations that are both language-specific and domain-general. Generalized claims such as Dediu and Levinson’s require evidence for all of these processes. But most of them do not leave fossil evidence, and genetic clarification is unlikely given how poorly we understand simpler phenotypes. For example, though the language is expressed through articulate speech today, the anatomical capacity for speech cannot by itself be taken as a proxy for language. The peripheral organs have to connect with the internal phonological, syntactic and semantic representations, and nothing in the
fossil record is ever likely to tell us: (a) what those representations were like; or (b) whether the human brain had yet formed the necessary connections between, e.g., phonological representations and vocal output. This does not bode well for the type of argument Dediu and Levinson advance, but let us examine the evidence they present.”

What about evolution of general cognitive structures in our prehistory? The emergence of working memory, for example, has remained hotly debated (Belfer-Cohen & Hovers, 2010). It is important to me here since working memory capacity has been implicated in a big way in language and cognition (Wen, 2016). Further, contemporary theorisation considers working memory and selective attention as primarily the same processes involving the frontoparietal brain networks (Engle, 2002). Brain imaging data suggest that learning to knap stones in a complex manner over an extended period uses the frontoparietal network (Stout, Toth, Schick, et al., 2008). This network plays a key role in selective attention. More recently bilingualism has been shown to enhance selective attention itself (Chung-Fat-Yim, Sorge, & Bialystok, 2016). However, switching and shifting call for inhibition and the ACC has been shown to perform this job (Abutalebi & Green, 2008; Abutalebi et al., 2011; see Table 2.1).

With newer evidence, the evolutionary timeline is pushed further back, suggesting an even earlier emergence of certain cognitive powers in Homo sapiens (Lewis & Harmand, 2016). Spatial cognition emerged 500,000 years ago (Wynn, 2002). However, working memory capacity in humans developed much later (Wynn & Coolidge, 2017). Working memory is linked to selective attention and also is a core component of the executive control system (Engle & Kane, 2004). This aided in complex goal-oriented action planning and creation of more subtle artefacts. Such hominoids could plan future action and inhibit undesirable actions. This must have been the first stages of evolution of the fluid intelligence that comprises of key cognitive systems. It is likely that this enhancement in working memory is also linked to the emergence of the computational structures that led to language. If we can assume that these hominids were already using one or more languages, then it is possible also to assume that working memory provided the necessary cognitive glue for bilingualism (Chung-Fat-Yim et al., 2016). The emergence of working memory capacity matches with the time when the frontal lobes enlarged (Coolidge, Wynn, Overmann, & Hicks, 2015). More specifically the central executive component of the working memory was probably the key responsible for more complex actions

<table>
<thead>
<tr>
<th>Cognitive process</th>
<th>Task</th>
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<tbody>
<tr>
<td>Inhibitory control/conflict resolution/conflict monitoring</td>
<td>Stroop task, Simon task, stop-signal task, Flanker task, Attentional Network Task (ANT)</td>
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<tr>
<td>Attentional control/selective attention</td>
<td>Dichotic listening task, Posner cueing task, visual search, ambiguity resolution in figures</td>
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<tr>
<td>Switching/set shifting</td>
<td>Non-linguistic task switching, card sorting tasks</td>
</tr>
<tr>
<td>Working memory maintenance</td>
<td>Word span, digit span tasks</td>
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and many executive control-related functions in hominins (Coolidge & Wynn, 2009) around 100,000 years ago. Current research shows that language itself requires multimodal integration of both visual and verbal information in real time and this calls for working memory (Huettig, Olivers & Hartsuiker, 2011; Mishra, 2009). Children with poor working memory capacity and attentional ability also show deficits in language learning and use. Working memory and complex task planning led to higher sophistication in artefacts such as shells and weapons (Henshilwood & Dubreuil, 2009). The symbolic nature of this activity may have been a precursor to language. Cognitive archaeological theories may have caveats. Tattersall (2016) asks whether archaeological artefacts should be taken seriously as proxies for cognitive mechanisms. For example, it is not clear what the links could be between the findings that *Homo heidelbergensis* could make a sophisticated stone tool and if they had necessary cognitive resources for a language.

Working memory and executive control may not be enough for linguistic interaction. A sophisticated machinery for social cognition should be in place. Among other skills, hypersociality has been suggested to have been an important trait that evolved in *Homo sapiens* particularly (Marean, 2016). These *Homo sapiens* could create robust social networks which changed many things. In addition to hypersociality, they also developed elaborate psychology to learn complex skills. Strong social skills and cognition led to the establishment of ethnolinguistic communities. The manner in which the social cognitive skills and executive control skills synchronised and led to complex cognition in *Homo sapiens* was unique. Prosociality seems to build a strong platform for shared systems that may include language, culture and also technology (Hare, 2017). For example, the evolution of joint attention to any task could be one manifestation of prosociality.

Joint attention is central to learning and also the performance of a joint action (Moore & Dunham, 2014). Language use among monolinguals or bilinguals is an example of joint action. Prosocial attributes can facilitate such joint actions. Humans have evolved this special talent to coordinate their thought and action with regard to others. Language and communication depend heavily on this attribute. Joint actions also entail a high degree of cognitive flexibility. This may include synchronising responses and inhibiting them when inappropriate to the context. Bilingual language use includes all of this within a social context (Green & Abutalebi, 2013). Infants quickly show many social skills that include orienting towards faces and sounds that are relevant and also interest in the environment (Machluf & Bjorklund, 2015). For example, the orienting of attention and gaze as a function of social cognition offers clues about how complex mutual cognition such as language learning may be achieved Posner (2011). Unless infants are tuned to socially relevant stimuli such as faces and eyes, there might not be much language learning.

Speakers and hearers continuously synchronise their speech acts with one another (Pickering & Garrod, 2004). Although Berwick and Chomsky (2017) suggest that computational capacity for language appeared in anatomically modern humans some 60,000–80,000 years ago, it is not clear from their account if it co-evolved with social skills and psychology for learning. It is likely that bilingualism developed as a function of such hyper-sociality (since bilinguals must also transact
across cultures) and sophisticated, complex cognition. Although there is more or less agreement that apart from *Homo sapiens* other early hominins (with whom they overlapped and at times interbred) did not have language, *Homo sapiens* themselves developed bilingualism because of their social cognitive skills supported by a newly evolved neural mechanism for manipulating two languages.

The emergence of bilingualism, therefore, can probably be understood as a consequence of language diversification and intermixing. Unless different groups of *Homo sapiens* developed different language at distant locations, we do not expect a situation for bilingualism to arise. Although, by this time, the *Homo sapiens* had evolved the ability to learn and handle two languages. What is important is to find out if the modern *Homo sapiens* powered by their extraordinary cognitive and social skills and enlarged parietal and frontal areas were in a position to learn one another’s language and become bilingual? Assuming that language itself is of relatively recent origin (60,000–80,000 years; other anthropologists date the emergence of complex cognition to 50,000–45,000 years only), and the diversity of languages to be acquired as two systems must have taken time, we can assume that bilingualism is probably of recent origin. However, to my knowledge, there have not been any strong suggestions so far on this topic, except one which holds bilingualism to be older than monolingualism. It is possible that in this intervening period, brain networks for switching, shifting and inhibiting developed that fully supported bilingualism as and when the social and cultural encounter happened.

It could be that linguistic and cognitive functions were later adaptations by mechanisms and neural structures already in place. Ardila (2016) proposes that many contemporary cognitive functions seen in humans such as working memory, inhibition, goal planning, and so on can be seen as modifications on some pre-adapted traits (see Table 2.2).

Ardila (2016) says that both linguistic skills and sophisticated executive control functions evolved in parallel in our 1,500,000 years of evolution. Thus, most complex functions can be traced back to some fundamental functions. Human cortex had already developed the ability to select context-appropriate action and inhibit

### Table 2.2 Different cognitive actions and the processes that serve them

<table>
<thead>
<tr>
<th>Cognitive ability</th>
<th>Pre-adaptation(s)</th>
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<tbody>
<tr>
<td>Grammatical language</td>
<td>Perception of actions</td>
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<tr>
<td>Calculation abilities</td>
<td>Finger knowledge</td>
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<tr>
<td></td>
<td>Spatial relations in language</td>
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<tr>
<td>Reading</td>
<td>Visual perception</td>
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<td>Cross-modal associations</td>
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<td></td>
<td>Spatial perception</td>
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<tr>
<td>Writing</td>
<td>Constructive abilities</td>
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<tr>
<td></td>
<td>Cross-modal associations</td>
</tr>
<tr>
<td>Meta-cognitive executive functions</td>
<td>Perception of actions (grammatical language)</td>
</tr>
</tbody>
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Adapted from Ardila (2016)
others that were not required, which came handy when bilingualism emerged. Similarly, with growth in the linguistic and social complexity of language use and learning, the demands of bilingualism necessitated changes in cortical functions without corresponding changes in the structure. This is what Ardila says when he cites Ridley (2004), suggesting that a great many human cognitive functions have evolved with few changes in the brain structure.

2.4 Contextualising the Brain

Deacon (1997) proposed that the utility value of language influenced selection pressure on the genetic modification that led to its faster acquisition. This is evident with the fluidity with which children acquire a language. Selection favoured biological changes that led to the development of critical brain structures necessary for managing two languages. Hagen (2008) speculates on the evolution of bilingualism and offers some interesting suggestions. His theory refers to social situations that might have led to bilingualism. Hagen thinks that Lenneberg’s notion of a critical period of language development is not useful when one wants to account for how our ancestors learned the second language. Gradually developing needs for social and cultural interaction then must have made adults acquire the language of their interlocutors for trade or to maintain social harmony. Thus, the notion of a critical period cannot explain how adults could learn a second language and become bilinguals. Although mastering a second language is more effortful for adults than for children, with the right kind of motivation adults can also learn a second language.

Further, bilingualism must have helped in social conflict resolution. Hagen (2008) also provides a range of archaeological evidence that suggests our ancestors were always at war and often very violent. These violent wars were necessary for gaining control over the other hunter-gatherers in the vicinity. Hagen wonders, given this background, how it is possible that adults who were at war found time to learn the language of their enemies—it was neither useful nor possible to learn the language of your enemy when what is important is to fight and kill and survive. However, this does not explain why today many adults learn the languages of others even when there are wars and other communal violence. Commenting on Hagen (2008), Hirschfeld (2008) echoes a similar thought. He says that our hunter-gatherer ancestors lived in peaceful security and multilingualism was a selected evolutionary trait since it was helpful. It is possible that with evolution and changing circumstances our social brain has evolved to acquire skills that may not be useful at once but would contribute towards the development of a larger culture. Thus, learning the language of the enemy might help in negotiating and conflict resolution. Natural selection must, therefore, have preferred bilingualism since it was good for our ancestors’ social life in many ways—both for the transaction of ideas and also resolving conflict.

Bilingualism is cultural; it involves exchanges between two cultures related to languages involved. Herrmann, Call, Hernández-Lloreda, Hare, and Tomasello
(2007) have suggested that humans have a specially evolved faculty for cultural intelligence. This allows them to understand the intentions of others, to acquire new skills from others and also to develop a social bond. However, we do not know at what stage of evolution or because of which factors such a specialised skill might have evolved. As Hagen (2008) proposes, if humans were constantly at war with one another, it is less likely that such cultural intelligence might have evolved easily.

Even if human brains had the necessary hardware to engage in symbolic activity such as language use, it called for cultural evolution to start this process (Arbib, 2016). Cultural evolution led to shared awareness and transfer of symbolic knowledge. Learning one another’s language for good was also linked to this parallel evolution of language-ready brains and language-using brains. Thus, mere development of the computational ability (of the type Chomsky proposes) was not enough. Humans had to understand that this rich symbolic capacity called for shared action. And such actions called for the exercise of crucial cognitive skills such as monitoring, inhibition and conflict resolution. Work in the area of computational comparative neuroprimatology informs that the widely popular mirror neuron system as seen in both humans and higher primates might have evolved both as a result of biological and cultural evolution (Ramachandran, 2000). Central to its claims lies the observation that agents mentally simulate others’ actions even when they are not performing these actions. Taking others’ perspective is also linked to this hypothesis, which is probably central to bilingual communication.

Contemporary studies show that bilingual speakers know which language to use to whom just by looking at the face of an interlocutor Woumans, Martin et al., (2015). Bilingual speakers also show the influence of cues present in their environment on language planning (Li, Yang, Scherf, & Li, 2013). Thus, bilingual speakers tag language to particular faces and scenes. The ability of the brain to tag language to specific contexts should have evolved to support bilingualism. Therefore, apart from cognitive mechanisms, the sensitivity of the brain to such contextual cues was essential for bilingualism. Although we have no idea about the exact nature of the evolution of bilingualism, we can make an attempt to join the dots. This has to be relating to the cognitive systems that helped both in achieving control and contextualised actions socially.

2.5 Development of Attention and Brain Networks

The last section in this chapter deals with the evolution of core brain systems that have been implicated in complex cognition. Much of the evidence has come from brain imaging studies in the last few decades. No fossil record will tell us how the brain networks for complex linguistic and social functions developed in earlier times. Developmental neuroscience data throw light on the evolving networks shaped by experience and learning. Data from rs-fMRI (resting state functional magnetic resonance imaging [fMRI]) show that critical functional networks in the human cortex start developing during gestation itself (Hoff et al., 2013). These
networks further keep developing in strength and size until age 2 years and beyond. Children normally turn out to be good bilinguals if they grow up in a bilingual context from an early age (Bialystok, 1991). Further, children can also learn a second language very quickly when they are 6 or 7 years or even younger. It is likely that by this time their brain networks supporting attention and working memory as well as abilities to switch voluntarily have matured. However, children with developmental language impairment or autism do not show such ability. Developmental dyslexia, for example, seems to manifest similarly for both first and second languages. Alerting, orienting and executive control networks appear to differently subserve cognitive control in bilinguals. However, it is hard to say based on current findings whether these networks develop in bilingual children differently or if there is a different maturational time course compared with monolinguals. Rueda, Rothbart, McCandliss, Saccomanno, and Posner (2005) trained 4- and 6-year-old children on executive attention task and measured both behavioural and brain activity on the Attentional Network Task (ANT). They found that significant improvements were observed between ages 4 and 6 years. EEG (electroencephalogram) data showed increased amplitude for the N2 component in the frontal areas (ACC), signifying increasing cognitive control.

Core primary brain networks are already in place in neonates and resemble adults’ networks, while some significant higher-order networks develop over 2 years (Gao, Alcauter, Smith, Gilmore, & Lin, 2015). This may suggest that even when there is no language production and much active use, some brain networks are already in place (Fig. 2.6). As cognitive demands grow, more sophisticated networks and connections develop. Here one can ask, do such developments differ

![Fig. 2.6 Brain networks in children and adults. The connections among nodes indicate dynamic functional connectivity during cognitive processing. (Fair et al., 2007)](image)
between children/infants exposed to bilingualism and those who remain in monolingual contexts? Does language context and use as well as exposure change brain networks differently? It has to be kept in mind that these networks that are later implicated in the control of higher cognition and language are already in place whether the child finds himself in a monolingual or bilingual community. However, the language environment and early input should play a role in how these networks mature in bilinguals and monolinguals.

Both attention orienting and executive control evolve steadily over childhood (Posner, Rothbart, Sheese, & Voelker, 2014). Children develop the ability to orient attention towards relevant stimuli and also to disengage attention when needed. This flexibility also includes the capacity to monitor changes in the environment. Posner and colleagues have mapped the different trajectories of these developments in both very young infants and children. Importantly, performance at 7 months predicts performance at 7 years. Thus, children with different abilities in executive control acquire and use language differently. Since managing two languages calls for extra executive control resources, it is likely that only those with a well-endowed capacity for attention control are going to be better bilinguals. While it is tempting to view superior executive control as a by-product of managing two languages, is it also possible that efficient brain networks help one become an excellent bilingual in the first place? Naturally, not everyone can be an effective user of language or a bilingual due to sensory and motor deficits, even if bilingualism is rampant in the environment. I wish to argue that sensory, executive and motor resources required for the efficient practice of bilingualism are much higher (inhibition, switching and shifting) than for monolingualism. Therefore, developmental neuroscience data should be looked at carefully to answer some of these questions. Understanding these will help in speculating how they might have evolved during evolution to support bilingualism.

Unfortunately, we do not have much neural evidence of neural changes when children learn a second language. Only well-executed and controlled longitudinal studies can reveal how one becomes bilingual and who can maintain the level of skill needed to benefit later as a function of plasticity. It is clear from current research that it is the quantum of bilingualism in practice expressed through variables such as proficiency and fluency (Singh & Mishra, 2012, 2013) that predict executive control advantage. Therefore, it is logical to expect that those bilinguals who had trouble in the early acquisition or sustenance of bilingualism are not going to show any plasticity-related changes in the brain. Although it is not an evolutionary question, it is important to know how some core mechanisms that support bilingualism evolved and how much time they took to mature. There is also little agreement with regard to a ‘critical period of bilingualism’. If some children have weak attention components, and therefore they could not be skilful practitioners of bilingualism, then they are going to perform poorly on control tasks measured later, independent of their bilingual status. This, of course, has entered into debates concerning the influence of bilingualism on executive control but has not been studied carefully with properly designed longitudinal studies.
The rs-fMRI data shows that during infancy important brain networks tracking different perceptual and cognitive tasks develop in a hierarchy. The primary networks appear first, followed by the attention networks and, finally, all the important executive control networks appear and long-distance functional connectivity develops (Clohessy, Posner, & Rothbart, 2001). Gao et al. (2015) measured the brain activity of infants in a longitudinal design starting from 1 month to 1 year of life and examined the maturational features of nine important brain networks. Most importantly, the authors wanted to know whether socio-economic variables influence how these networks change with time. The study revealed different maturational time-points for different networks and their appearance followed the predicted patterns. Importantly, socio-economic variables correlated with the strength of default mode network and the sensorimotor network. Thus, the ability to learn from stimuli lies with the efficiency of such networks. In contemporary cognitive neuroscience, analysis of the default mode networks of the human brain along with resting state networks has assumed significance (Fig. 2.7). It comprises important brain areas that show high functional connectivity with one another. The assumption is that such networks play a crucial role in important cognitive functions (Raichle, 2015).

Using the cueing paradigm, Posner and Petersen (1990) proposed three important subsystems of the human attention system: alerting, orienting and executive control. Behavioural studies with both children and adults show individual differences in the functioning of these networks. Brain imaging data show different cortical and subcortical networks that subserve these functions. For example, the ventral and dorsal orienting systems support orienting. In a large sample study of children, Mezzacappa (2004) observed that only children from financially sound homes did well on executive control tasks. More specifically, they were better on the
alerting network. Older children were better in the orienting network. These data indicate a strong and early influence of socio-economic factors on the development and efficiency of important attention network during infancy and childhood. If that is so, then it is also possible that infants from well-to-do houses and where additionally bilingualism is in practice may develop superior attention networks compared with children from lower socio-economic homes and where parents speak one language. Albeit, this conjecture has been controversial recently where researchers have not been able to replicate findings where the modulating role of socioeconomic variables on bilingual executive control advantage is concerned.

Cognitive psychological studies have shown that attention does not return to a location soon after it has been disengaged from one location (inhibition of return) (Klein, 2000); therefore, attention moves to newer locations and objects. This movement of attention must have been important for our early survival. This inhibition of return of attention to a recently attended location has been suggested to facilitate foraging. Even archer fish, which do not have very well-developed cortaxes, show inhibition of return of attention (Gabay, Leibovich, Ben-Simon, Henik, & Segev, 2013). Our early ancestors must have often needed inhibition of return to survive and it also comes in handy when finding new objects (Klein, 2000). Interestingly, highly proficient bilinguals have been shown to disengage attention from stimuli rapidly and are capable of deploying it to novel objects. It appears that attentional mechanisms such as inhibition of return are ancient and have helped both for survival and cognition.

Nevertheless, it is important to know whether infants (Fig. 2.8) from bilingual and well-to-do homes are already in possession of superior and efficient attention networks compared with their monolingual peers, before they become fluent bilinguals? Or do these existing advantages lead them to become good bilinguals in the first place? Those who have acquired both languages at birth would have practised bilingualism longer than those who have learnt the second language later. They have managed language conflict longer and, therefore, bilingualism should have a greater effect on their brain networks than the late bilinguals. It is becoming very clear that executive control, and attention in particular, play a central role in both acquisition and maintenance of many important cognitive skills. Of course, these systems keep maturing throughout adulthood, tackling newer challenges.

The ACC mediates conflict monitoring (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999). Many recent studies that have used brain mapping during language and attention tasks in bilinguals and monolinguals have implicated the important role of this area in conflict management during language selection. With regard to the question of the evolution of such important brain networks that might have supported bilingualism, comparative neuro-automatic studies show that the ACC is an older structure and its white matter has changed significantly in recent evolution in humans. Allman, Watson, Tetreault, and Hakeem (2005) report that the Von Economo neurons increase in their number between infancy and early childhood in the ACC and anterior insula. This suggests a gradual neurodevelopmental increase in the executive control system that is important for bilingual language support. Acquisition of a second language changes neural organisation both functionally and
structurally. Importantly, early acquisition and constant practice of a second language boost the cortical density of critical brain regions that also control cognitive systems such as attention and working memory. Mechelli et al. (2004) measured structural plasticity using whole brain voxel-based morphometry in Italian–English early bilinguals, Italian–English late bilinguals and English monolinguals. Brain imaging data showed that the cortical thickness of the left inferior parietal cortex was higher for the early bilinguals than in the late bilinguals and monolinguals.

Are there brain areas that are critical to learning a second language? Although successfully learning a second language is again an outcome of complex interactions between motivation, cultural–linguistic contexts and age of acquisition, some brain areas seem to play a key role. Recently, Barbeau et al. (2016) trained adults in the second language for 2 weeks and measured brain activity using fMRI at two timepoints. The inferior parietal lobule (IPL) showed higher activity at the second timepoint. Others have found that the grey matter density activity in this area correlates with higher second-language proficiency and competence (Abutalebi, Canini, Della Rosa, Green, & Weekes, 2015). The authors make an interesting assertion based on the results suggesting that the activity of the IPL may actually indicate one’s later success in learning a second language rather than being a consequence of language learning. Other evidence suggests that this area also plays a key role in spatial attention, although its right homologue plays even a greater role in covert attention. Neuroimaging investigations show that in the bilingual brain, the
lateral prefrontal sites control both syntactic and rule-based representations. Additionally, the basal ganglia control inputs to the prefrontal areas (Buchweitz & Prat, 2013). Therefore, the bilingual brain shows this typical neural organisation which seems to accommodate language control. Constant practice of bilingualism leads to plasticity-related changes in the frontal lobes, IPL and ACC (Abutalebi et al., 2013). Children who are early and simultaneous bilinguals should develop these brain areas and their specialisations much more for language control than late bilinguals.

Albeit the empirical study of ‘consciousness’ has been elusive in cognitive sciences, it is now possible to theoretically understand what exactly it does. I have mentioned that working memory and selective attention were important systems that have played a key role in cognitive evolution. Consciousness has been proposed to include goal planning, conflict resolution, task switching, and so on (Hommel, 2017). These are important aspects of executive control systems. Consciousness feeds these systems in many task scenarios. Actions are planned and executed only when one is conscious with regard to the action’s outcome. Let us see the utility of such theoretical thinking for bilingualism. Bilinguals need to select one of the languages, considering its contextual appropriateness voluntarily. This selection is also dependent on understanding what is on the interlocutor’s mind. Therefore, voluntary control of action is important to handle languages better. However, it is not clear if language selection is similar to other actions in a cognitive sense. Studies have shown that bilinguals can voluntarily switch between two languages and also other tasks (Gollan & Ferreira, 2009; Gollan, Kleinman, & Wierenga, 2014). It is tough to say when consciousness emerged in *Homo sapiens* in the way it is understood scientifically today. However, if consciousness is understood as the mechanism that is closely related to action and executive control (Hommel, 2017), then it was in place before the computational capacity for language emerged. In his model, Chomsky does have an intentional–conceptual component, but we do not know anything about its evolution or if it was specific to the language system or other systems. Given this scenario, apart from just executive control systems, aspects related to consciousness and action control should be studied with regard to the question of bilingualism.

### 2.6 Summary

In this chapter, I have explored the evolution of bilingualism with regard to the material and cognitive conditions that led to its emergence. In the absence of any material record, it is unwise to abandon the evolutionary developmental view and wholeheartedly adopt a mutation view. While there may not be any evidence to show that language or bilingualism evolved incrementally, we also cannot explain why a strange mutation might have suddenly happened. Data from cognitive archaeology and related fields can point to which cognitive skills must have arisen more or less at what timepoint. It appears that core mechanisms required to handle two
languages evolved when *Homo sapiens* developed sophisticated social cognition. Bilingualism became a norm, and further practice of it influenced brain systems. Bilingualism also spread socially as it helped forge economic and cultural relations. However, its evolutionary selection probably had a larger agenda that included enhancing cognitive reserve. It was essential for general cognitive health.

Although no fossil proxy can indicate the timeline of the evolution of monolingualism or bilingualism, available evidence we can still help us make some sound guesses here. Bilingualism seems to have evolved out of cultural pressure, but more so when the *Homo sapien* brain developed the neural and cognitive resource for social cognition, especially when the brain had the right networks to shift, switch and inhibit responses. Many of these systems had their origin in earlier times, and it may be possible that many early hominins had these capacities. However, their use in language management is probably very recent. I emphasise that to understand how the brain acquired bilingualism, we have to know what the brain needs to practice bilingualism: linguistics, cognitive archaeology and language evolution. Evolutionary psychology and cognitive anthropology have attempted to understand how humans developed language and cognition in general. In this chapter I have discussed the various perspectives on this issue. I think that bilingualism emerged as an interaction between socio-cultural forces and neural development. It is not yet settled whether anthropological artefacts should be used as proxies for mapping the origin of complex cognitive behaviour. More recently, even our understanding of the routes and nature of human migration out of Africa is changing (Pagani et al., 2016). New evidence suggests that anatomically modern humans might have emerged in Asia Liu et al. (2010). Human teeth dating back 100,000 years ago were found in a cave in China. While some believe that we had no contact with the Neanderthals, others have gone as far as attributing the currently seen language diversity to the Neanderthals. Further, the range of cognitive systems that control bilingualism in the brain is not finite, nor are they the result of neural activity in specific networks. What is known is the mechanism that is likely involved in language switching and monitoring, including inhibition. However, one can only speculate when the systems might have evolved.

References


3.1 The Cognitive Basis of Bilingualism

Bilinguals manage two languages during speaking. However, this language management has different connotations with regard to different things. A key question is if they exercise ‘control’ during such management. Language management is linked to how they have acquired their two languages, current proficiency, environment, age and other factors. Many excellent textbooks have discussed these issues exhaustively (Kroll & De Groot, 2009). Psycholinguistic models such as the revised hierarchical model (RHM) (Kroll & Stewart, 1994; Fig. 3.1) or the bilingual interactive activation (BIA+) model (Dijkstra & Van Heuven, 1998) speak of developmental connections between the native (L1) and the second (L2) language non-selective activations, respectively. Importantly, most of these models make assumptions about the underlying psychological or neurological mechanisms. These assumptions have a crucial bearing on the question of control. The models and their assumptions have influenced our understanding of domain-general executive control and its relation to language control. Questions related to switching and shifting have been critical in linking cognitive control to such processes.

3.2 What Goes on in a Bilingual Mind?

3.2.1 Translation

What bilinguals do depends on what kind of bilinguals they are. Simultaneous, sequential early and late bilinguals process their second language differently. Most bilinguals in the world learn a second language later in life—they may achieve native language-like proficiency through immersion and practice. A fundamental observation has been that in such bilinguals, language control mechanisms are
linked to their performance on L2 neural representations of languages may be different for those who acquired both languages together as opposed to separately. For example, the switch cost during naming differs for balanced and nonbalanced bilinguals; non-balanced bilinguals translate the second-language words into the first language as they learn the second language, which gradually changes with proficiency (Kroll & Stewart, 1994). Interestingly, even high proficient bilinguals show unconscious translation between the languages when using their second language (Mishra & Singh, 2016; Sunderman & Priya, 2012).

Let us consider the translation recognition task (Sunderman & Priya, 2012). In this task, pairs of words (one in L1 and the other in L2) are given to participants to judge. At times, the second word is phonologically related to the translation of the first word. Studies have shown that bilinguals take more time in rejecting these pairs since they quickly activate the translation of the first word and this interferes with their processing of the second word. Interestingly, this is seen in bilinguals who have already mastered the second language. We can also label such activations as language non-selective cross-language activation. Many eye tracking visual world studies have also shown such unconscious parallel language activation (e.g. Blumenfeld & Marian, 2007; Mishra & Singh, 2014, 2016). For example, using the visual world paradigm, Mishra and Singh (2016) demonstrated that Hindi–English bilinguals automatically translate spoken words into the other language. Unbalanced but high (L2) proficient Hindi–English bilinguals listened to a spoken word and looked at four pictures on a computer screen (Fig. 3.2). One of the pictures was a phonological cohort of the translation of the spoken word. Eye movement data showed that listeners immediately oriented their gaze towards the object whose name overlapped with the translation of the spoken word (Fig. 3.3).

These findings suggest that the Hindi–English bilinguals, who were clearly unbalanced, spontaneously activated the translations of the spoken words. Due to spreading activation, these words further activated the phonologically related forms. These activations have been suggested to be automatic since experimental participants do not seem to have conscious control over them. For instance, Wu et al. (2013) showed that native language is automatically activated when words in the
second language are incidentally processed in a task that did not require explicit language processing. However, the question of translation is critical as it forms the core assumption in a major model (RHM). Why do high proficient bilinguals translate? Shouldn’t the need to translate decrease as L2 proficiency increases? Ma, Chen, Guo, and Kroll (2017) observed that low proficient L2 learners showed higher semantic interference in a translation recognition task. A similar finding was also shown by Guo, Misra, Tam, and Kroll (2012) with high proficient bilinguals. This means that the low and high proficient bilinguals activate translations for either similar or different necessities. While high proficient bilinguals have now been shown to activate translations, it is not certain that it is only for reasons of need. There have been suggestions that bilinguals activate translation equivalents if they have more time in hand. For example, Ma et al. (2017) did not find translation effects at a short stimulus onset asynchrony (SOA) but only at a long SOA. But data from a visual world eye-tracking paradigm suggests that both low and high proficient bilinguals show translation affects around 200 ms of word onset (Mishra & Singh, 2014).

Recently, Costa, Pannunzi, Deco, and Pickering (2017) have suggested that these effects may have little to do with translations. They argue that the English lexicon of second-language speakers is organised differently to that of native English speakers (Fig. 3.4). Taking the example of Chinese–English bilinguals, they argue that an association between train and ham is formed independently in the English lexicon of Chinese–English speakers because of the association between their translations huo che and huo tui. Thus, ham might be activated while listening to train because of this direct association and not because their corresponding translations are acti-
vated. The same probably goes for Indians and others who learn English as a second language at school. Thus, the translation route might not be active in bilinguals who achieve high proficiency but still might show the effects normally attributed to translation. Even bimodal bilinguals translate signs into words and vice versa. Giezen and Emmorey (2016) found that bimodal bilinguals who knew ASL (American Sign Language) showed facilitation in the production of ALS signs for pictures when they were preceded by words phonologically related through translations. One can say that these individuals have learnt the sign language later in life and they must have learnt these signs through translation. Therefore, the translation route is still active when they have to function unimodally. The fluency of such bimodal bilinguals in controlling the co-activation of these two systems is also linked to their executive control (Emmorey, Giezen, & Gollan, 2016). Nevertheless, it is clear that all kinds of bilinguals show automatic contact between the lexicons of their two languages at phonological and semantic level. This contact is often dubbed as non-selective parallel activation. The need to control one while focusing on another is linked to such spurious activations. Therefore, understanding the nature and extent of cross-linguistic activations during bilingual language processing is critical in understanding the control involved.

Fig. 3.3 Proportion of fixations for the translation competitor and distractors. Parallel activation was higher when the spoken word was in L2. High proficient bilinguals activated the translations earlier than low proficient bilinguals (Mishra & Singh, 2016)
3.2.2 Inhibition

Inhibition is the mechanism that has attracted most interest and controversy in defining how bilingualism influences cognitive control. Inhibition means to inhibit an emerging response which is not goal appropriate. As discussed in the last section, bilinguals activate both lexicons simultaneously even if there is no need for it in a given situation. Therefore, they need to inhibit one response in order to articulate the correct language. Activating both languages irrespective of the current goal is one significant characteristic of the bilingual mind itself. The bilingual mental control model of (Green, 1998) first proposed a general purpose inhibitory control mechanism at work in the bilingual brain. Later, many neuroimaging studies have shown that the anterior cingulate cortex (ACC) and some prefrontal areas coordinate this activity in the bilingual brain. Green’s suggestion was that a general purpose control system (also used for non-linguistic tasks) in the bilingual brain inhibits task-inappropriate language. This led to the idea that bilinguals should differ from monolinguals on a non-linguistic tasks such as the Stroop or the Stop Signal task. Early studies by Bialystok, Craik, Klein, and Viswanathan (2004) found such effects, which were then replicated by others. For example, Mishra and colleagues found that highly proficient Hindi–English bilinguals show a lower Stroop cost than low proficient bilinguals on an oculomotor version of the Stroop task (Singh & Mishra, 2012).

**Fig. 3.4** Illustration from Costa et al. (2017) showing the structure of the L1 and L2 lexicon in Chinese–English speakers as a function of second-language learning. By the end of learning, associations are formed between the two unrelated words *train* and *ham* because of the association between their corresponding translations in Chinese: *huo che* and *huo tui*. 

3.2 What Goes on in a Bilingual Mind?
Picture naming has been classically used to study the mental dynamics of language control (e.g. Abutalebi & Green, 2007; Costa & Santesteban, 2004). Researchers often ask participants to name pictures in mixed blocks or pure blocks—mixed blocks elicit language switching. There is a cost involved in switching between languages which has been interpreted to indicate inhibition (Meuter & Allport, 1999). Bilinguals have been shown to apply sustained inhibition to their first language, particularly if they are unbalanced bilinguals. This is because in such bilinguals the native language words activate strongly and have to be inhibited (Peeters & Dijkstra, 2017). Of course, different types of bilinguals, depending on their language fluency and dominance, may show different levels of switch cost. Switch cost apparently indexes the reactive form of inhibitory control (Philipp & Koch, 2009). Is there a proactive type of inhibition involved in language production?

Braver has offered theoretical accounts for reactive and proactive types of inhibitory control Braver (2012). But Green’s initial idea which led to many studies with bilinguals considered a reactive form of control. It is evident that Green had in mind the cued naming paradigm with mixed languages where people switch between languages based on the instruction. Recently Ma, Li, and Guo (2016) allowed people more preparation time as they named digits or pictures. It was observed that they were able to overcome the need to apply the reactive type of inhibition and applied a more proactive type of control. This was reflected in the switch costs. Proactive control can be understood as top-down control which sets action plans for successive trials. Proactive control in this context does not mean that applying it will lead to no activation of the unwanted lexicon. Inhibitory processes can also continue over time. For example, if one inhibits a response on a certain trial then when the same item comes up it will also be inhibited. This means that inhibition continues to be applied when items that were previously not considered become relevant again (Koch, Gade, Schuch, & Philipp, 2010). This is also seen during cued language naming. People take a long time to name in the language that was inhibited in the previous trials because re-activating an inhibited language is cognitively costly.

Are there other types of inhibitory mechanism? Forstmann et al. (2008) distinguished between two types of inhibitory systems. One is selective and applies to specific types of stimuli and the other, which is a general inhibitory system, is non-selective. The general non-selective system is top-down. Shao, Roelofs, and Meyer (2012) found that selective and non-selective inhibitions are applied differently during object naming with monolinguals. When distractor pictures are presented with target objects to be named, speakers have to inhibit those. These objects could share meaning or form with the target objects. Speakers’ scores on the Stop Signal task correlated with their non-selective inhibition in object naming but not with selective inhibition. In the context of bilingual object naming one can think of inhibiting one language schema which is top-down and non-selective while selective inhibition relates to specific objects. Using event-related potential (event-related potential), Shao et al. (2014) further showed that quantum of selective inhibition applied to reduce distractor interference during object naming correlates with the N200 component. This component has been linked with inhibitory processes. While these explanations with regard to monolingual naming are straightforward, it is difficult
to explain how selective inhibition works for the bilingual. For the bilingual speaker, every object presented for naming activates its name in both the languages. But do bilinguals indeed inhibit a response or are other mechanisms involved? As of now, we don’t know the answer. In their meta-analysis, Hilchey and Klein (2011) argue that if two groups differ in inhibition in a Stroop-like task, then the difference between the groups should only be observed in the performance on the incongruent trials. The incongruent trials in a Stroop-like task require conflict resolution. However, when they performed the meta-analysis they found that bilinguals were faster on all types of trials, not necessarily only on incongruent trials. This means that it was not inhibition leading to lower Stroop effects but a superior executive control system which was responsible for the overall faster reaction times in bilinguals. The general overall speed advantage is linked to executive control. Hilchey and Klein (2011) proposed that the inhibitory control account is insufficient and argued for a superior executive processing advantage in bilinguals. However, they offered no theoretical explanation as to why bilinguals should show even this overall reaction time benefit. Mishra and colleagues have also observed that apart from specific Stroop advantage, bilinguals were also faster on neutral as well as congruent trials (Singh & Mishra, 2012, 2013, 2016). They suggested that both a general speed advantage and an inhibitory control advantage can be present in such bilinguals. However, this does not sort out the theoretical difficulty of explaining what exactly is leading to such effects.

My intention here is not to get into the many psycholinguistic theories on naming but rather on how inhibition as a control system is involved in naming. Of course, one can imagine a bilingual speaker as two monolinguals and each language may require some sort of control system. Nevertheless, the current arguments and debates focus on whether there is a general purpose control system common for both linguistic and non-linguistic systems and whether the manifestations of this control system is mostly or exclusively in the domain of inhibitory control. The data on proactive or non-selective inhibition point towards a top-down mechanism. Whatever the mechanism may be, the other important issue is whether the exercise of such a control system leads to enhancement of capacity, which in turn extends to non-linguistic inhibition. Although theoretically plausible, the data in support of these arguments are controversial. It is possible that the experiments so far have not been able to pinpoint the exact type of inhibitory mechanism that bilinguals use during language control, which should only be seen on certain tasks. A wide range of tasks that have been used to measure inhibition have their impurity (Miyake et al., 2000). To what extent a particular task mimics the process under debate is also questionable. The gross assumption is that tasks such as the Stroop or Stop Signal task do call for inhibition, which is then seen in the dependent variables. Nevertheless, inhibition is certainly a key mechanism in different aspects of language control both in monolinguals and bilinguals. However, how far linguistic inhibition is functionally linked to the enrichment of executive control remains contested.
3.2.3 Task Switching

Inhibition of one language and selection of another may involve switching—switching between languages requires executive control (Green, 1998). Brain imaging data show that frontal control areas are active when bilinguals switch between languages. For example, in an early brain imaging study, Price, Green, and Von Studnitz (1999) found different cortical areas to be active when bilinguals switched between languages and when they translated words. While translation engaged the ACC, switching was found to engage Broca’s area. Different bilinguals differ in their degree of switching depending on a range of factors. The social context within which they live and use language decides how often they switch, and their language proficiency decides if they pay a higher or a lesser cost while switching. Switching is, therefore, a diagnostic feature of bilingualism. It can involve switching between two tasks or action plans.

Language switching has been examined widely in different populations using the picture naming task (Meuter & Allport, 1999). When bilinguals switch from the dominant to the less dominant language they pay a cost, and this cost has been shown to be asymmetrical. Higher costs are seen when switching from the less dominant to the more dominant language than vice versa. Others have observed that early and balanced bilinguals may not show this asymmetry (Bobb & Wodniecka, 2013). But why does switching matter when we are trying to understand bilingual language control? Switching matters as it involves executive control in a big way. Many brain imaging studies have shown that areas that are involved in general executive control show activity in switching (Hernandez, Martinez, & Kohnert, 2000). For example, the dorsolateral prefrontal cortex is active when people switch between languages.

Could switching be the key to understanding the cognitive advantages that bilingualism may bestow? One way to understand this is to have bilinguals divided into good and bad switchers and then examine them in executive control tasks. The idea is that if someone switches a lot he must be exercising executive control a lot. Or we can indirectly examine whether bilinguals are better than monolinguals in task switching. Prior and Mcwhinney (2010) found that bilinguals are better (incurred lower switch cost) at task switching than monolinguals. Switching also indicates flexibility in mental set shifting. Wiseheart, Viswanathan, and Bialystok (2016) also reported that bilinguals demonstrate lower switch cost when they shift between non-verbal tasks. Balanced and non-balanced bilinguals may show different switch rates. Verreyt, Woumans, Vandelanotte, Szmalec, and Duyck (2016) administered Flanker and Simon tasks to bilinguals who were either balanced or unbalanced based on their switching. Balanced bilinguals who were frequent switchers outperformed others on these executive control tasks.

The frequency and types of code-switching in bilinguals should be a straight outcome of their socio-linguistic context. Why do bilinguals code-switch and how often? If we know these data, it will be important in explaining any executive control advantage they may display. Let’s take the case of Brussels in Belgium. Brussels
is officially bilingual. It is important to know that Belgium has been a zone of both
language and political conflict where bilingualism has played a crucial role. While
the upper part of Belgium is predominately Dutch-speaking and the lower portion is
French, Brussels is bilingual. Treffers-Daller (2010) observed that while older bilin-
guals in Brussels switched more, this is not the case with the younger bilinguals.
One of the reasons the author pointed out was to do with knowledge of the correct
version of Dutch. People who knew this purer version switched more. The younger
generation might not switch more because of their heightened awareness of social
conflict and also to assert their ethnicity. Although there are numerous studies
examining both the links between switching and executive control as well as costs
in mixed naming, it is not clear how such mechanisms may differ in various
contexts.

In one study, Lawson and Sachdev (2000) examined the nature and extent of
code-switching in bilinguals in Tunisia. Code-switching was observed only when
speakers spoke with their in-group members and not outsiders. That is, bilinguals do
not code-switch when they perceive someone as an outsider ethnically. In Basque
country, schools make sure that teachers switch between Basque and Spanish regu-
larly so that children use both languages as their first languages (Lasagabaster,
2011). However, we do not know whether the bilinguals there switch a lot. Of
course, there won’t be much switching if bilinguals have to stay with monolinguals
who speak only one language. In many speech communities, switches may be more
intra-sentential, and in some others they may be more inter-sentential (Poplack,
1988). Poplack reported the difference in the extent of code-switching among
Puerto Rican speakers of Spanish and English in New York, USA, and the French–
English bilinguals in Ottawa, Canada. The socio-linguistic reasons for their switch-
ing in their contexts are different. The reasons for code-switching and its quantum
in a certain bilingual population could be many (Gardner-Chloros, 2009). This
means that the quantum of code-switching in the everyday speech of bilinguals is
also dependent on who he/she talks to. This leads to a very important link between
levels of social conflict, the frequency of switching in certain bilingual places and
the degree of executive control these bilinguals may require.

Code-switching and frequency directly influence the engagement of the execu-
tive control mechanism (Poplack, 2001). Bilinguals also code-switch more when
they are in the bilingual ‘mode’ than when they are in the monolingual mode
(Grosjean, 2008). While in monolingual mode, bilinguals should inhibit the activa-
tion of the language not in use. While in bilingual mode, both languages are active.
Switching, if any, therefore, should happen when bilinguals are in the bilingual
mode. More often the bilingual speakers of a community converse in the bilingual
mode; they are likely to switch more. Therefore, the number of bilinguals and
monolinguals and the frequency in which they have interactions also decides the
quantum of bilingual mode experienced. When the bilinguals are in a minority
within a community, they are less often in the bilingual mode and, therefore, they
have less opportunity to switch. If they are in the majority, then they have more
chances to mix and switch languages. An interesting point on this is related to the
executive control of bilinguals in a bilingual majority as opposed to a bilingual
minority context. In the first context, they switch more often and in the latter context, they switch less but inhibit the inappropriate language more often while at least conversing with monolinguals. It’s understandable that even when bilinguals are communicating and switching language, the unused language has to be inhibited. However, the nature of inhibition in these two cases is probably different.

Bilinguals also switch if they come across any language cue that forces their systems to reconfigure. The influence of social context on bilingualism is discussed in detail in Chap. 6, but some examples are necessary here. Bilinguals are sensitive to cues that are linked to particular languages. In one study, Zhang, Morris, Cheng, and Yap (2013) found that Chinese–English bilinguals became slower speaking in English when they saw a Chinese face. Similarly, in another study, Roychoudhuri, Prasad, and Mishra (2016) found that Bengali–English bilinguals were slower in naming objects in English when they saw some Bengali-specific culture pictures. These studies show that bicultural bilinguals activate their native language instantly when they see a visual cue related to that language. However, such activation comes into conflict with naming in English. Thus, bilinguals switch covertly when they become sensitive to some visual cues. This then affects actual language production. These data also indicate that bilinguals’ code-switch may be unintentional most of the time depending on cues they experience in their environment. Thus, the frequency of switching between languages has a lot to do with social context.

The adaptive control hypothesis (Green & Abutalebi, 2013) has attempted to link the frequency of code-switching in a particular context to executive control. The proposal gathers its strength from the observation that bilinguals switch in a given context depending on different variables. One of these is the knowledge of the interlocutor. In some cases, the bilinguals rarely switch languages as they use different languages for different contexts. In that case, the demands on executive control are less. Some others fuse both the languages in the same sentence, making heavy demands on control. Others have to switch between the two languages in different contexts constantly. These dual code-switchers have to bring in lots of control. According to Green and Abutalebi (2013), these three types of bilinguals develop three different types of control systems. Now then, the task is to find out which bilingual belongs to which type. This may require socio-linguistic analysis.

For example, how do we classify the Telugu–English bilingual students at the University of Hyderabad and Hindi–English bilinguals at other northern universities in India? In India, many prefer to use the L1 at home and English at the office. Thus, they may not switch as such, but again it depends on the context and who one is speaking to. A bilingual encountering a monolingual will inhibit the second language and its activation; there will be no need to switch in such a case. If he speaks to another bilingual, then switching will be mutual. However, depending on the perceived proficiency of the interlocutor, the speaker may prefer to switch or not switch. In one recent study, Hartanto and Yang (2016) tested two groups of bilinguals in Singapore, divided based on their switching contexts, on the recommendations of the adaptive control hypothesis. As predicted, bilinguals from a single-language context (which did not require switching) showed a higher switch cost (on a non-linguistic switching task) than bilinguals from a dual-language
context. The authors argued that it is the habits of switching which are reflected in how they easily switched in a non-linguistic task. This research deviates from early approaches as it takes into account the speaker’s linguistic and social habits—what exactly they do as bilinguals in a given context.

Given this background, one wonders what kind of bilinguals researchers have been studying when they have been reporting either the presence or absence of bilingual advantage? Do we know what their history of language switching is? Are they in the majority or minority in their speech community? What is their frequency of switching during a day? What kind of executive control can one expect in a bilingual who does not switch at all if he resides in a community where switching is considered bad pragmatically? Also, we have little data about switching situations in many parts of the world where there are bilinguals. Unless we have good data on these factors, it is difficult to understand the cognitive and psycholinguistic implications of bilingualism.

### 3.2.4 Monitoring

Monitoring the environment for any conflict is an essential component of executive control. When there is more conflict that needs attention for resolution, then there is a higher engagement of executive control (Botvinick, Braver, Barch, Carter, & Cohen, 2001). The dorsolateral prefrontal cortex and the ACC are involved in such conflict monitoring and executive control (Kerns et al., 2004). Switching between languages during bilingual conversation is interlocutor dependent. Bilingual speakers need to monitor their environment to know when to switch constantly. It is, of course, dependent on the individual language profiles of the bilinguals. The point is not that bilinguals have to switch but the mechanism through which they switch. This calls for monitoring, which is part of the executive control system (Miyake et al., 2000). Monitoring in a task situation includes alertness and also vigilance. It may also include awareness of recent performance in the task. For the bilingual speaker, monitoring includes evaluating who is a bilingual and who is monolingual in a communication context. It also includes monitoring for conflict. However, it is not clear what monitoring for conflict may mean. Is it to monitor the inconsistent switching patterns of an interlocutor or the self? If bilinguals always monitor for conflict in the environment, then it is possible that this itself should enhance their executive control. Essentially, conflict can mean even the slightest change or even incongruency between stimuli and response. With higher conflict, bilinguals should engage in higher executive control. Costa, Hernández, Costa-Faidella, and Sebastián-Gallés (2009) showed that when monitoring demands are high, bilinguals bring in greater executive control. They had administered the Attentional Network Test (ANT) where they manipulated the percentage of incongruent trials in blocks, thus manipulating monitoring demands. For example, when in a given block of trials only 20% of trials are either congruent or incongruent, then monitoring demands are much lower. However, if congruent and incongruent trials are mixed in equal
numbers, then uncertainty is very high. The authors observed that bilinguals differed from monolinguals only for the block where monitoring demands were high. Later, Mishra and colleagues also replicated this with an eye tracking saccade paradigm and found similar results (Singh & Mishra, 2013).

Conflict management and monitoring could be applicable to both linguistic and non-linguistic stimuli for a bilingual. Neuroimaging evidence suggests that when presented with conflict, bilinguals adapt better and show less activation in the ACC (Abutalebi et al., 2011). In this study, the authors compared bilinguals and monolinguals on the Flanker task when they were scanned in an fMRI (functional magnetic resonance imaging) experiment. However, how the bilingual brain adapts to linguistic and non-linguistic conflict is not that easy to explain. While the conflict in a Stroop or Simon task may require one to be attentive to response inhibition, it is not yet settled whether the same mechanism is used during language production as well. Moreover, the term ‘monitoring’ has been used differently by researchers who have performed fMRI studies and those who have carried out behavioural studies. For example, the studies by Costa et al. (2009) and Singh and Mishra (2013) use monitoring in the sense of alertness or being attentive to constantly changing stimulus. Monitoring in these cases refers to higher uncertainty. But in some of the fMRI studies conflict monitoring just refers to resolving trials with conflict (Abutalebi et al., 2011).

A recent study has shown that when working memory demands are high, bilinguals tend to do well on tasks that demand response inhibition (Jiao, Liu, Wang, & Chen, 2017). For example, Jiao et al. (2017) administered Flanker, go-no-go and modified Flanker tasks to young bilinguals and monolinguals. The apparently modified task required higher working memory. The bilinguals showed better performance when they did this modified task but not in the normal version of it. The authors suggested that the bilingual advantage in response inhibition can only be seen when the working memory demands are high. This conclusion is similar to that which Costa et al. (2009) had reached with their monitoring conditions. But the critical question is what is it that these bilinguals do so that their executive control system is only optimally active when the situation is demanding. Without such information about the participants, it is not easy to interpret why higher difficulty leads to higher recruitment of executive control.

Do all bilinguals monitor? I think very few experimental investigations have directly examined this question. The demands of monitoring may vary depending on the bilingual context. For example, if in a social situation one does not expect sudden appearances and reappearances of interlocutors for whom one may need to change control settings, monitoring may be less. For example, in a city like Beijing as opposed to New Delhi, the need to monitor for other bilinguals speaking English as their L2 may vastly differ. The situation is entirely different for Chinese–English or Hindi–English bilinguals in New York City. While in one case sighting a fluent speaker of L2 may be rare (Beijing) it may be commonplace in some other contexts (New Delhi). In other situations the onus of control may differ altogether (New York City). In a recent study on older patients, Clare et al. (2016) found no evidence that Welsh–English bilinguals had any advantage over monolinguals. The authors...
suggested that these bilinguals often do not need to inhibit English as most people in that community speak English. This means there is less need to monitor the context and choose which language to pick and which one to inhibit. Similarly, Padmanabhuni et al. (personal communication) did not find any evidence that their older Telugu–English bilinguals had any advantage on executive control tasks. It is possible that such bilinguals mostly speak Telugu at their homes and have little opportunity to practice bilingualism. Therefore, monitoring is dependent on the context present in society. While it is easy to induce monitoring in a laboratory setup with varying contextual demands, future large-scale studies should take into account how the environmental context of the bilinguals influences the monitoring mechanism. No study has compared bilinguals from different cultures where predominant language modes could be different. Thus, our understanding of monitoring in experiments is limited since we have little information about the participants’ background in terms of the practice of bilingualism except for some data from self-reports.

In summary, what bilinguals monitor in different socio-linguistic scenarios may differ widely. Bilinguals may monitor for either other bilinguals or monolinguals in a particular context. In a social setting where most people are either bilinguals or multilingual, the nature of monitoring may depend on other variables. In such cases, speakers perhaps need to monitor the nature of switching and also language proficiency. This is valid in India since bilinguals have different levels of proficiency in English as a second language (Singh & Mishra, 2012, 2014). Therefore, both high and low proficient bilinguals may need to monitor differently for interlocutors. Such a problem does not arise where there are some bilinguals and most others are monolinguals or predominately speak one language. Thus, studying how context modulates monitoring requirements in different bilingual socio-linguistic scenarios may throw light on the language use–executive control nexus.

A recent trend in this research field is to include bilinguals who speak a range of first languages (e.g. Paap & Greenberg, 2013). These are mostly students in western universities and are readily taken as a bilingual sample, while the monolinguals come from the local population. However, in such a case, one cannot be certain how, for example, a Chinese–English bilingual undergraduate student switches and shifts or inhibits compared with a Korean–English bilingual. If language experience had to show any effect on executive control, then these two bilinguals should have different experiences. After all, these bilinguals in western countries such as the USA or UK do speak their mother tongues among fellow citizens who are also immigrants, and their cultural context of speech use and switching may vastly vary. It is naive to assume that all those coming from very different cultures who are in student dorms and live on campus are practicing bilingualism to the same extent. Criticisms apart, such studies have at least forced us to think about whether the effect of bilingualism on cognition is more subtle than previously thought. It is also possible that while some bilinguals in some cultures are more adept at detecting a target, others in another culture are better at initiating a response. Some others may be good at both of these. Therefore, it is probably necessary to erect the hypothesis knowing fully well what kind of bilingualism is in practice in the participant’s culture and
which exact mechanism may be in use for language control. Glossing over such issues may lead to null results that may confuse the field further rather than adding clarity.

### 3.2.5 Attentional Disengagement

More recently, attention has emerged as a critical component that could explain some of the differences between bilinguals and monolinguals (Bialystok, 2017). Bilinguals can focus attention more actively on the language they are currently considering as well as being able to disengage from it faster when the goal changes. Bialystok and colleagues (Friessen, Latman, Calvo, & Bialystok, 2015) found that bilinguals perform better at parallel search in a visual search task than monolinguals. In this type of search, one has to keep in mind two different types of features that define a target and where many distractors can resemble the target making the search difficult. Similarly, Chung-Fat-Yim, Sorge, and Bialystok (2017) presented ambiguous figures to bilinguals and monolinguals and examined whether bilinguals were better at finding the alternative picture with fewer cues. Ambiguous figures that have two representations pose a perceptual problem. The authors found that bilinguals were better at such a task and suggested that bilinguals have higher selective attention.

The Posner cueing paradigm can reveal attentional engagement and disengagement (Posner, 1980). In this paradigm, a brief peripheral cue first appears that orients attention towards it. After either a brief or a long delay, a target appears at either the cued location or at another location. The task is to just press a key when one sees the target. Many studies have shown that when the target appears at the valid location immediately after the cue, then response times are facilitated, whereas if the delay is longer, it turns into inhibition. This phenomenon, dubbed ‘inhibition of return’ (IOR) suggests that attention does not return to the recently attended location. Klein (2000) has suggested that this indicates the foraging nature of attention that wants to move around and find new objects in the vicinity. Mishra et al. (2012) performed an interesting experiment using this paradigm with Hindi–English bilinguals who were students at an Indian university with Hindi as the native language but were proficient in English as their second language to different degrees. The idea was to examine whether L2 proficiency would correlate with any attentional difference between the groups. The results indicated that the high proficient bilinguals showed early onset of IOR, indicating rapid disengagement of attention from the cue compared with the low proficient bilinguals. Moreover, they were also overall faster (on all kinds of trials) than the low proficient bilinguals. These results show that bilingualism aids in better attentional movement.

Do bilinguals select better and therefore orient their attention better towards the relevant stimuli or are they just good at disengaging attention from the irrelevant stimuli? Attentional disengagement from a stimulus or an event can be visualised in many different ways. Mishra and colleagues looked at disengagement from a
peripheral cue towards which attention had been oriented using the Posner task (Mishra et al., 2012). In conflict tasks such as the Flanker tasks, congruent and incongruent trials are presented at random in a mixed block. The incongruent trials require conflict resolution, whereas the congruent trials do not require this. While most researchers calculate the mean reaction times to these trials and arrive at the conflict effect, it is possible that the trial that immediately precedes the current trial can influence its processing. This was examined by Grundy, Chung-Fat-Yim, Friesen, Mak, and Bialystok (2017) in a study with younger bilinguals. They wanted to investigate group difference on the sequential congruency effects (SCEs) rather than mean reaction times. If one has encountered an incongruent trial recently, then this can lead to higher sensitivity to conflict. If the following trial also happens to be an incongruent trial, then this may help overcome conflict. However, for congruent trials, this may not work. The study showed that bilinguals show a higher SCE than monolinguals, suggesting that they could disengage attention from the previous stimuli better than the monolinguals.

It should be noted that in the context of a conflict task where all types of stimuli are presented randomly, disengagement has to happen for both congruent (relevant) as well as irrelevant trials. It is not clear from studies whether these mechanisms should be linked to bilinguals differently. In a social communicative framework, disengagement of attention from one interlocutor and engagement to another makes sense. Alternatively, one may assume that bilinguals are good at focusing on the context-relevant language and do not allow interference from the irrelevant language. It will perhaps not be sufficient just to say that bilinguals need to pay higher attention to the relevant language and therefore this enhances their selective attention. This does not automatically explain why they should also be good at disengagement. Semantics apart, it does seem appropriate to suggest that bilinguals seem to have some higher control with attention. However, it is too early to decide which component of attention is particularly modulated by the bilingual experience based on current studies.

An important point to note here is that disengagement gives the flavour of top-down attentional control. Chung-Fat-Yim et al. (2017) make a dichotomy of internal and external attention. Both of these forms of attention are in some sense related to bottom-up and top-down control. In classical language, one can use words such as endogenous and exogenous attention as well. Are both forms of attention control available to the bilingual? From the studies by Bialystok and colleagues, it appears that bilingualism aids in the development of the endogenous type of control. It is possible that bilinguals are also better at orienting attention to peripheral cues. This orienting of attention should help them to look at appropriate social signals in the environment so that they can link up the correct language. The adaptive control hypothesis (Green & Abutalebi, 2013) refers to the bilingual’s ability to be alert to such signals that can inform about language. Thus, orienting to cues should be understood differently compared with disengaging. Interestingly, an early study by Hernandez et al. (2010) found no orienting advantage for the bilinguals. They did not observe any difference between the groups with regard to facilitation or IOR, which was seen in Mishra et al. (2012). Hernandez et al. (2010) examined whether
bilinguals have better top-down visual attention control using a visual search paradigm. Bilinguals and monolinguals were given a shape to remember and then search for it. On the search panel, a cue either appeared within a valid (target) or an invalid (distractor) shape. The idea was to see whether bilinguals can avoid the distractor. The data showed that cueing made no difference to the bilinguals, who probably were not that affected by the distractor. This may mean that bilinguals could control their attention better and search for the object faster amidst distractors that share attributes. It is important to note that here attention has been conceptualised as a distractor avoidance mechanism.

Compared with manual reaction time measures, eye movements can reveal more details about attentional mechanisms. Eye movements have been causally linked to attention (Hoffman & Subramaniam, 1995) and a host of studies in primates show how superior colliculus and the frontal eye field neurons control attention and saccades (e.g. Wurtz & Goldberg, 1972). While many have used manual reaction time measures to study visual search, few have used eye tracking. In a study with manual measures, it is not possible to say when someone starts looking at a target and when he makes the discrimination. Eye movements towards potential targets can be fast and people can then press a key conveying their decision. In a study with manual measures, it is not possible to say when someone starts looking at a target and when he makes the discrimination. Eye movements towards potential targets can be fast and people can then press a key conveying their decision. In a comprehensive study with Hindi–English bilinguals, Singh and Mishra (2012) used eye tracking to study how bilinguals avoid distractors in a Stroop task they adopted which was used previously by Hodgson et al. (2009). The task required participants to make a saccade towards a colour patch which was similar to the colour of a word presented in the centre. It is well-known that in the Stroop paradigm the word meanings are activated automatically. In such a situation, it was expected that people would activate the meaning of the word and start looking at the colour patch whose name matched with that. However, if they had to follow the Stroop instructions, then they had to inhibit eye movements towards this distractor. If this had been a manual task, there would be no way to see if people made a quick decision of going towards the target or they first looked at the distractor and then corrected their saccade. These contingencies of decision-making are not part of the reaction time data.

Singh and Mishra (2012) divided their participants into high and low proficient bilinguals. Their results showed that high proficient bilinguals were faster in initiating a saccade towards the correct colour patch, avoiding the interference caused by the distractor. But low proficient participants had a greater number of errors and probably suffered more interference. The study revealed for the first time how eye tracking measures could be used to understand attentional mechanisms that are modulated by bilingualism. This is important since those who have obtained null results so far have mostly done manual studies. It is very much possible that different methods that reveal different aspects of cognitive processes will lead to different results about the same phenomena. Mishra and colleagues later also used eye tracking to study response inhibition in a double-step task with such bilinguals and found group difference (Singh & Mishra, 2015). Interestingly, in such studies, high proficient bilinguals always had faster saccade latencies overall. In another study, Singh and Mishra (2016) examined anticipatory eye movement control in low and high proficient bilinguals. The design was novel enough to extract how people manage to
programme saccade when there is some conflict about the initiation time. Participants were asked to programme a saccade only when the colour of the target circle turned green from orange. This task requires fine coordination between selective attention and saccade programming. The design required participants to be alert about the onset of the green signal and not launch the saccade when it was still orange, the timing of which was uncertain. However, to perform better on the task ideally they should have prepared but not executed the saccade when the target circle was orange. Essentially, the task examined action preparation and execution under uncertainty. The high proficient bilinguals were faster and had fewer errors then the low proficient bilinguals. Such fine-grained evidence about cognitive control cannot be obtained with manual data.

It has been shown that manual response times may be very different from saccade latencies for the same task. This was recently highlighted by Ratiu, Hout, Walenchok, Azuma, and Goldinger (2017) who compared bilinguals and monolinguals on a visual search task using eye tracking. The authors wanted to know whether bilinguals are better at target detection or response initiation. The authors suggested that if they are better at just detecting the target among distractors, then the saccade latency of the first fixation should be faster. If they are better at initiating a response, then they should be faster at pressing the key after visual detection of the target. If their advantage lies in a mixture of the two, then they should just be overall faster on all these measures than monolinguals. This kind of graded hypothesis about the exact mechanism influenced by bilingualism is much better than just predicting gross effects. The participants were first presented with a target object and were asked to find it among similar and dissimilar distractors. The search type was complex, in which the distractor that looked almost like a target had to be avoided. The authors performed three experiments with different degrees of search questions and difficulties. The results revealed no group difference for first saccade or overall speed. In one case, bilinguals were slightly faster in decision-making than monolinguals. However, the null results have their limitations too. The sample size was too low, and bilinguals came from different cultures and spoke a variety of first languages. Thus, we don’t know to what extent they were practicing bilingualism and to what extent the group was homogenous with regard to language experience.

### 3.3 Summary

In this chapter, my main aim was to first raise a set of questions around bilingualism and its necessary links with cognition. There may be other mechanisms but the ones discussed here are critical. As we can see, most researchers have studied these mechanisms, linking them one way or another to bilingualism. My premise is that unless we understand what mental and cognitive mechanisms define a bilingual, it is not possible to link bilingualism to cognitive and executive control. In the absence of such clarity, people end up describing the same thing differently from their unique vantage points. The mechanisms discussed in this chapter may all have
common underlying connections. For example, recent theorisation on executive functioning assumes that individual performance on diverse cognitive components may be correlated (Miyake & Friedman, 2012). At this point, we are not in a position to demonstrate how the various psycholinguistic performances by bilinguals use common cognitive mechanisms. I have attempted to explain the mechanisms that are a part and parcel of being bilingual. They, of course, may occur to different degrees in different people because of many other factors. Monolinguals, on the other hand, may not display such skills. When it comes to studying bilingualism and cognitive control, it is important to know which basic mechanism is at work. Does switching or monitoring or social awareness lead to significant neuroplasticity? Does this depend on the particular cultural and linguistic climate prevailing in the country? We have not yet answered such questions. What we have before us are different sets of results that do not replicate. It is one thing to say that the practice of bilingualism does not affect the enhancement of cognitive processes; it is another to say that depending on the type of mechanism bilinguals use often, a certain specific cognitive process is going to be modulated. Right now most researchers are taking an either/or position. When they are replicating one another’s studies with very different bilinguals they are assuming that these various bilinguals have similar mechanisms to the same extent. That is clearly problematic. From the next chapter onwards, I build the narrative around these core mechanisms.

References


Chapter 4
Cognitive Advantage of Bilingualism and Its Criticisms

4.1 Is There Any Cognitive Advantage of Bilingualism?

Whether the practice of bilingualism leads to some noticeable advantage in the cognitive domain or not is an empirical question. Intuitively, it makes sense to assume that constant practice of any cognitively challenging skill should lead to neuroplasticity. This strengthening of critical brain networks then should confer a domain-general cognitive advantage. However, the results have posed more questions than given answers. Do highly fluent bilinguals who have been using both languages over years find this challenging? Or do only low proficient and struggling bilinguals find it challenging and therefore such practice should lead to neuroplasticity? Non-replicable results have led to suspicion about the whole issue. But, can we say null results are sacrosanct? Can’t those who have obtained null results be accused of methodological errors? The very question of executive control in the bilingual has many components and studies have only replicated some of them. The following list gives an idea of the range of things that researchers have considered during replication:

(a) There is no clarity regarding which component of executive functions is influenced by bilingualism.
(b) There is no clarity about what exact neural control mechanisms bilinguals use during language control.
(c) It is not clear if indeed a domain-general control mechanism influences both linguistic and non-linguistic control.
(d) Task impurity affects how we interpret the task findings with relation to bilingualism.
(e) Replication failures are mostly with behavioural data.
(f) There are very few replication failures with neural data.
(g) There have been mostly conceptual replications and very few direct replications.
(h) Cultural issues have not been included.
Miyake and colleagues present executive functions as a collection of functions such as selective attention, working memory, inhibition and also monitoring (Miyake et al., 2000). Now the question is which aspects of these functions is improved in a bilingual as a function of bilingualism? According to most theorists, everyday practice of a skill leads to neural changes in the brain and this may show up in an advantage when we perform other tasks. Practice-induced neuroplasticity leads to stronger functional and also at times structural connections in neuronal networks. In the case of bilingualism, selecting one language while inhibiting the other leads to strengthening of the inhibitory control system. This system is just one component of the executive control system. However, most foundational works in this area have supported this view that bilinguals actively inhibit the language that they do not intend to use at a certain moment. However, we are talking about language use and why our performance on some unrelated non-linguistic tasks such as the Stroop or Simon task or Attentional Network Task (ANT) should improve. The assumption is that these tasks mimic what may actually be happening in the bilingual’s mind. How do we know that all kinds of bilinguals in different sociolinguistic contexts are using similar strategies for language control?

Cognitive control includes alertness, selective attention and efficient adaption to challenging situations. Continual alpha rhythms of the brain indicate the existence of top-down cognitive control (Sadaghiani & Kleinschmidt, 2016). Braver (2012) proposed a dichotomy between reactive and proactive types of control. Reactive control is applied to inhibit a response in a reactionary manner. Proactive control is to remain alert and set task goals in a top-down manner so as not to allow conflict to happen. Some authors have suggested that bilinguals use proactive control mechanisms more than reactive and this helps them plan actions ahead of time. Valian (2015) suggested that we do not have the right task to measure executive control. Actually, while it is not clear if a particular task is measuring a particular construct (like Stroop measures inhibition), we also do not know which task mimics the mechanism that bilinguals use to control language. At this point in time, the debate on bilingual cognitive advantage is being pursued from several angles. The foremost issue is which mechanism explains any advantage for the bilinguals and which tasks manifest them. Variables such as language proficiency, switch rate, dominance, the age of acquisition or level of dominance influence executive control differently. Further, these correlations are different for children and adults as well as old people.

Some have argued that socio-economic status (SES) can explain any difference one might see between monolinguals and bilinguals. Socioeconomic factors remain very powerful indicators of mental functioning including intelligence and literacy achievements (Mani, Mullainathan, Shafir, & Zhao, 2013). Many developing and underdeveloped countries still remain behind in terms of material progress. These countries have many people who are illiterate as well as those who can’t afford any formal literacy. Interestingly, the percentage of bilinguals in such countries is also higher. The socio-economic argument has been tested and the proponents of the advantage theory show that such factors have no influence. Even poor children who are bilinguals outperform monolinguals on an executive control task. It has to do with the practise of two languages. Studies that have been performed in India, for
example, show cognitive and executive control advantage (Khare, Verma, Kar, Srinivasan, & Brysbaert, 2013; Singh & Mishra, 2012, 2013). Even those who have studied patients with regard to the onset age of diseases (e.g. Alladi et al., 2013) subscribe to the advantage theory. However, India still remains poor and many of its population are illiterate. We do not have any concrete data from countries such as China and Brazil or other African countries on such issues. In one study, Engel de Abreu et al. (2012) examined immigrant children in Luxembourg and found that even such children who are bilinguals executive control tasks than the resident monolingual children. Bilingualism, then, strengthens the brain networks irrespective of one’s material status. It makes sense since we are primarily talking about speaking (and not reading or writing) two languages.

4.2 Replication

Replications can be conceptual or exact. Both types of replications have their own advantages and disadvantages and inform theory accordingly. In the area of bilingualism and cognitive advantage, most replications have been conceptual (Paap & Greenberg, 2013). Since bilinguals differ so widely from one culture to another, replications often fail because of uncontrolled factors. More recently, there have been quantitative studies showing a number of positive and negative results for bilingualism. Francis (2012) examined how often so-called successful replications may actually be failures if one does not take into account the effect sizes of particular experiments and the sample size used: “Although experimental psychologists have long believed that successful replication is a way to demonstrate the validity of an empirical finding, this belief is not always true. When experiments have low or moderate power, there should frequently be experimental findings that fail to replicate a result, even if the effect is true. In such a situation, it is possible to have too much successful replication, which suggests some form of publication bias”. (p. 2012).

Paap et al. (2017) wrote that “we still adhere to the recommendation of Paap and Greenberg (2013) that a compelling demonstration of bilingual advantages in EF [executive function] require statistically significant advantages in different measures derived from at least two different tasks and that those measures must also show convergent validity.” Convergent validity demands that two different tasks that apparently employ the same component of the executive function should show high correlation. If that is not the case then only one of the tasks is relevant and researchers have no businesses administering many tasks together. Theoretically, if we knew which task best represents how bilingualism modulates the executive function, then one task will be enough. While at times Paap et al. (2017) make some sound comments against others those who have found advantages and how their methods or their analysis was weak or wrong, they themselves have not been careful about the methods. In most of their studies, the bilingual participants all had different first languages. Paap et al. (2015) also have contempt for those who have not used a
monolingual group. Of course, the original aim was to compare bilinguals and monolinguals and show that bilinguals are faster. But there are countries where one rarely comes across a monolingual, for example in India. How then should these hypotheses be investigated in India? Mishra and colleagues (Singh & Mishra, 2012, 2013, 2015, 2016) have consistently used language proficiency second language (L2) as a grouping variable and have found positive results. Furthermore, Mishra (2015) has argued that one should not even compare bilinguals and monolinguals since neuroimaging has shown that they may have a different neural organisation.

Prior and Gollan (2011) obtained a bilingual advantage in San Diego, California, USA (Paap took their samples from San Francisco). Paap’s rejection of Prior and Gollan’s study is based on the fact that they transformed their data and so on. While everyone is convinced that self-reports can be very deceiving and one must collect objective measures, Paap thinks self-reports are a valid measure. What I am trying to bring out here is the puritanical and high moral ground which replicators have assumed as if their methods are beyond questioning. That is problematic in the investigation of truth if that is ultimately the aim of replication. Also, for every researcher who finds himself in a certain socio-linguistic and bilingual context, the very questions and issues he may address could be different. For example, as mentioned earlier, it is difficult to find monolinguals in India, although in one study Alladi et al. (2013) performed their analysis comparing bilinguals and monolinguals. However, finding only Chinese-speaking monolinguals in any major Chinese city won’t be a problem. Therefore, one cannot claim that in order to establish bilingual advantage or disadvantage one has to take bilinguals and monolinguals. In my studies, I have reasoned that higher second-language proficiency could modulate executive control if we accept the fact that with higher L2 proficiency, bilinguals are more likely to practice bilingualism. If that is the case I do not see any problem comparing bilinguals who have high and low proficiency and not bother about monolinguals. This line of argument is also in consonance with Kroll and Bialystok (2013).

4.3 Publication Bias in Bilingualism Cognitive Advantage Research

Publication bias refers to the phenomenon where primary research dissemination outlets such as journals tend to publish positive results more often than null results. This leads to a situation where the field has many positive results but few replication failures published. Several reports suggest that psychologists are more vulnerable to publishing positive results than null results (Francis, 2012). Though null results can provide a check on the state of affairs of the field and its major theories showing problems, they themselves often do not pass quality checks. Publication bias could have its origins within the demands of the paradigm (Kuhn, 2012). Most scientists add on to the positive results and this gives the illusion of the theory being popular. Null results challenge the data and therefore are a problem for the existing theories.
Why are null results often not published? Many journals openly write that they will be very reluctant to accept null results or replications. They seek to publish articles that provide outstanding novel results. These results are often based on a small sample size and might have other methodological issues. Many commentators have remarked on the existing issues with the desire of psychology journals to only give value to novelty over methodological rigour (Francis, 2012).

Francis (2012) undertook an examination of publication bias in two different fields and the publications therein, looking at controversial papers in the area of extrasensory perception. The conjecture was that if the number of rejections of null hypotheses exceeds the number of expected null results, then the field may have publication bias. This means critical data are not yet available to readers to evaluate both sides of the story since such data have been suppressed. In a retrospective study of clinical research, Easterbrook, Gopalan, Berlin, and Matthews (1991) found that studies with significant results were likely to be published in journals with a higher impact factor. Ferguson and Heene (2012) remark that psychology’s aversion regarding publishing null results actually means it is less able to falsify its own theories. Such theories remain popular but they may be based on biased results. More recently, many researchers have been using statistical methods and meta-analysis to ‘see’ if there is publication bias in a particular field (Lane, Luminet, Nave, & Mikolajczak, 2016).

De Bruin, Treccani, and Della Sala (2015) looked into publication bias in the bilingualism executive control literature. They selected conference abstracts published between 1999 and 2012. They wanted to find out whether the studies in these abstracts that reported a positive result confirming the bilingual advantage got published in a journal more often, and this was indeed what the results suggested. Those abstracts which later got published had positive results supporting the advantage hypothesis. Is this methodology of linking conference abstracts and their acceptance into journals to demonstrate publication bias foolproof? Bialystok, Kroll, Green, MacWhinney, and Craik (2015) wrote a comment on this paper and challenged its methodology. Their argument was that conference abstracts often present preliminary data and are a poor choice for gaining knowledge about publication bias. If this is the case and conference abstracts are a poor choice, then we should wait for such an analysis comparing the journal acceptance rate for papers describing positive findings and negative findings. However, these data are yet not available. De Bruin, Treccani, and Della Sala (2015) did not consider the rejection rate of journal manuscripts reporting null or negative findings. Comparing this number with the acceptance rate for positive results would justifiably indicate publication bias. It was also not clear from the analysis by De Bruin, Treccani, and Della Sala (2015) whether they made a distinction between null results and negative findings. Bialystok et al. (2015) argue that it is only the negative results and their quantity and publication rate that will inform us whether a field has any publication bias.

The other approach to establishing publication bias and trends within a field is to use a bibliometric approach. This approach quantifies all published studies based on their support or challenge to a theory within a period and also includes citations. This way one can know within a period whether citations to positive or negative
findings dominate one another. Sanchez-Azanza, López-Penadés, Buil-Legaz, Aguilar-Mediavilla, and Adrover-Roig (2017) examined published studies in the area of bilingualism and executive control between 2005–2013 and 2014–2016. They classified studies into four categories: studies with clear positive results, negative results, ambivalent studies and studies that did not mention advantage. They also counted citations for these studies between these timepoints. The data showed that the number of studies that challenged the bilingual advantage theory grew significantly post-2014. Further, citations to such studies also overtook citations to studies describing positive findings post-2014. Although the number of articles publishing negative or null results during this period is fewer than those affirming the advantage, their popularity has certainly grown. For example, a meta-analysis by Hilchey and Klein (2011) that challenged the advantage theory has so far attracted 385 citations.

Kenneth Paap, one of the main protagonists of the ‘no advantage’ position, has consistently challenged the advantage view. According to him, those who have obtained the advantages have fewer subjects in their studies and also show a tendency to report positive findings. Bialystok and colleagues believe that Paap’s commentary appears to give rise to a false controversy and that there is nothing wrong with the positive results. Bialystok (2016) suggested that the use of certain types of analysis and also categorical hypothesising could lead to null results. In their 2011 review, Hilchey and Klein (2011) had also suggested that positive findings occur with small sample sizes, whereas one may get both positive and null results with large sample sizes. If the distribution is bigger, then, of course, bilinguals with different attributes will be represented in the sample. Figure 4.1 from Paap et al. (2014) shows the distribution of effects in studies with different sample sizes.

Figure 4.1 shows that as studies have fewer participants, they are more likely to get positive results. Further, when a researcher takes a small sample size he is likely to get a false positive. Then there is also the issue of convergence validity which Paap raises. When different tasks that measure executive function do not correlate there is a problem of interpretation. These issues make it highly problematic to trust the positive results as such. Interestingly, in other subfields of psychology people often use very small sample sizes and there seems not to be a big issue. Many studies in the area of psychophysics or vision research take only a sample of 15 or so people (e.g. Montagnini & Castet, 2007; Van Zoest & Donk, 2010). Is there a bias within subfields with regard to the question of number of participants (N)? Or is it a statistical question set apart from such considerations. If one looks at alternative hypothesis testing, such as the Bayesian models, many follow a method where sampling stops at a certain number. Power calculations as well project the N. Of course no statistical approach comes without its own troubles. The issue is whether people who have got positive results have got them because of statistical flaws and omission. Would their results change if these studies were conducted in a large sample of people?

Is publication bias to be found only in behavioural results? Paap et al. (2014) wrote a long theoretical paper questioning the existence of the bilingualism advantage. They examined whether neuroscience studies show bilingual advantage as
well. Neuroscience (EEG [electroencephalogram] and fMRI [functional magnetic resonance imaging]) studies depend on the correlation between neural activity and behavioural results. Paap et al. (2014) indicated several problems with some of the neuroscience studies that have shown a bilingual advantage. For example, Abutalebi et al. (2011) found evidence that the anterior cingulate cortex (ACC) shows less activation in the bilinguals than in monolinguals when they do a Stroop task. To them, this was evidence of higher conflict monitoring in the case of the bilinguals. However, Paap et al. (2014) believe that Abutalebi et al. (2011) have actually studied inhibitory control and not conflict monitoring since they simply calculated blood oxygen level-dependent (BOLD) signal strength in congruent and incongruent trials. Similarly, in an EEG study on conflict resolution in sentence processing, Moreno, Bialystok, Wodniecka, and Alain (2010) compared bilinguals and monolinguals and found that the N400 effect was higher for the bilinguals than the monolinguals. The authors suggested that this larger N400 effect shows the conflict resolution advantage of bilinguals over monolinguals. However, Paap et al. (2014) suggest that this shows bilingual disadvantage not advantage since more generally in event-related brain potential (ERP) studies N400 rises when there is difficulty in integration of meaning within context. If this is true it means that researchers have often interpreted effects and tasks convenient to their narrative. However, is there

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**Fig. 4.1** Plot showing frequency of positive effects (bilingual advantage) as a function of sample size. (From Paap, Sawi, Dalibar, Darrow, & Johnson, 2014)
something like a single and all agreeable definition of such ERP effects as N400 and P600? Many studies of language in psycholinguistics and cognitive neuroscience show that even until now researchers grapple with the actual interpretation of these effects. While N400 was known to show up more when there is trouble integrating semantics, many have also found this effect when people fail to integrate constituents syntactically (Hagoort, 2003).

So what is the way to actually study any bilingual advantage if it exists? Paap et al. (2015) wrote that “One possible roadmap for pursuing the specific circumstances for producing bilingual advantages was provided by Paap and Greenberg (2013) and could stand to be updated. Studies should start with a theory of how two or more languages are co-ordinated and specify which (if any) of the control mechanisms employ domain-general EF [executive function]. This should lead to the identification of the particular type (or combination of types) of bilingual experience that is most important to enhancing that component of EF. That critical experience should play the lead role in predicting which bilingual groups should have better EF and, in turn, be better than monolinguals. The groups should be matched on SES, immigrant status, culture and so forth using operationally defined measures. Tasks and measures should be selected that have demonstrated the convergent validity and, even then, it is best to have two measures, derived from two different tasks, included in the study so that one can rule out the concern that any obtained bilingual advantage in performance is task specific. The number of participants in each group should be determined in advance and based on a reasonable level of desired power. In estimating power a small effect size should be assumed given the meta-analysis reported by de Bruin et al. and the effect sizes reported in Hilchey and Klein (2011) and Hilchey et al. (in press).” This seems reasonable. However, most studies that have observed advantage have also considered three variables. No study can control all variables ideally—not even those which replicated and found null results considered all the variables in controlling their experiments.

In summary, is very difficult to establish publication bias in a narrow discipline only on the basis of a few null results. We don’t know why those null results could not be published. One needs to establish that studies with null results and negative findings were submitted and they were unfairly rejected by journals—this kind of data are yet not available. Therefore, from these articles that have concluded that the bilingual advantage is an outcome of populist positive results and suppression of negative findings, we do not know exactly what the theoretical concerns are. The reasons could be many, including both methodological problems and also individual differences.

4.4 Core Challenges Against the Advantage Theory

While replications will continue, it is important to examine the theoretical, conceptual and methodological challenges thrown up by those studies that aim for the death of a theory. What exactly have these studies attempted to say and where is the
locus of their attack? When someone attempts a replication (few have done direct replications) the authors are either dissatisfied with the analysis, the participant selection or the interpretation of the original study. It is never the case that a study has all of these flaws together. Those who do perform a meta-analysis also take an a priori position. Their selection of articles, if biased, may add further noise to the debate. How do we make sure that a meta-analysis that attempts to nullify a theory’s claims is itself not methodologically problematic? Let us examine one meta-analysis that actually led to a sustained attack on the advantage theory in recent times and which has been cited many times. The meta-analysis by Hilchey and Klein (2011) attacked a very core premise of the bilingual advantage theory. Hilchey and Klein began to look at studies that had used conflict tasks such as Stroop or Simon. Those studies were mostly on younger bilingual children who were compared with monolinguals. Hilchey and Klein argued that if inhibition is the core mechanism whose continual practice leads to a bilingual advantage, then one should not see bilinguals also performing better on congruent trials. Congruent trials do not have any conflict in such tasks; therefore, group difference on this task should not be seen. They found that studies that had claimed a bilingual advantage had observed this reaction time (RT) advantage for bilinguals on the congruent trials. They further found that in most of these studies bilinguals were overall faster than monolinguals. The studies that were considered had used different types of tasks: Stroop, Simon and Flankers. Based on their observations, Hilchey and Klein made two important points. They suggested that bilinguals may have an overall executive control advantage that makes them faster on all kinds of trials. They further claimed that bilinguals and monolinguals may not differ just on the inhibitory control aspect. This was a theoretical attack based on the tasks and their conceptualisation. If one believed in a specific inhibitory control advantage and one chooses a particular task to demonstrate this, then one must see a particular kind of effect. This was not found to be the case. Often some studies did show a bilingual advantage on the conflict effect (incongruent–congruent) but they also showed a general RT advantage (e.g. Bialystok et al., 2004). Hilchey and Klein proposed a model calling it the bilingual executive processing advantage. Although not many studies after their proposal have found this overall RT advantage, it still remains conjecture. The importance of this meta-analysis was that it offered a conceptual alternative. It is actually not clear if indeed bilingualism advantage is because of inhibition or monitoring or both. Hilchey and Klein’s meta-analysis thus appeared to suggest an alternative theoretical possibility. More recently, however, Klein observed that the overall RT benefit for bilinguals is not seen often and they have modified their initial suggestions (Klein, 2016).

Another important review of the literature was by Valian (2015). Valian did not outright support the analysis of Hilchey and Klein (2011), or for that matter the null results of Paap and Greenberg (2013). Valian made two assertions. She suggested that maybe there is a bilingual advantage, but that these advantages are invisible when compared with monolinguals since at times monolinguals may have higher executive control. Executive control in monolinguals might be enhanced because of video game playing and such demanding tasks. Therefore, even if bilingualism
could have some positive effect on executive control per se, they remain invisible during group comparison. This proposal does not outright deny the existence of any cognitive advantage because of bilingualism but opens a new theoretical possibility. Valian also addressed the question of task impurity. Importantly, she looked at all the results that were published then in terms of the age of participants. It was obvious that the effect of bilingualism on young children, younger adults and older adults was different. Therefore, replication failures were specific to one age group since executive control as such varies a great deal as a function of age. Valian’s analysis did not suggest that there is no possibility of finding any advantage given the current state of the art. She also indicated that maybe we do not yet know the right kind of task to capture advantage in bilinguals. She suggested that studies do not often show a difference between bilinguals and monolinguals since many monolinguals may do cognitively more demanding tasks than bilingualism and this may make them similar to bilinguals when it comes to performance on executive control tasks. This is an important insight since this alerts us to look at variables other than bilingualism that can enrich the executive control system. It is very easy to see the difference in the suggestions of Valian and that of Hilchey and Klein. Whereas Hilchey and Klein criticised the inhibitory control approach taking into account the global RT advantage, Valian looked at the issues more holistically.

Antón et al. (2014) examined whether bilingual and monolingual children differ on the ANT, which is often used to measure different attention networks. The authors implicitly tested the assumption that bilingualism may influence the attentional networks. Their large-scale comparison did not reveal any difference between bilingual and monolingual children. Previously, Costa, Hernández, Costa-Faidella, and Sebastián-Gallés (2009) had shown that bilinguals have some advantages on the ANT compared with monolinguals but these are very restricted to certain situations, for example, when the task becomes very demanding. Antón et al. (2014) generalised, saying that maybe one does not find the bilingual children to be any better on the ANT than monolinguals. They wrote “Certainly, we want to avoid generalizing the observed lack of bilingual advantage to other age groups, and as already discussed in Duñabeitia et al. (2014), our claims are exclusively endorsing the conclusion that the so-called bilingual advantage in tasks focusing on participants’ attention skills is inexisten, or at best, extremely inconsistent and elusive”. This study and its conclusions do not rule out the possibility of the bilingual advantage on other attention tasks. Von Bastian, Souza, and Gade (2016) examined a large sample of young adult bilinguals. They tested four different hypotheses linked to the bilingual advantage. Various tasks were administered that measured inhibition, monitoring, shifting and general executive functions. Their results did not show any particular role of bilingualism on these tasks. Further, variables such as the age of acquisition, proficiency and usage were controlled for. This study was large enough to conclude that bilingualism may have a very limited effect on specific aspects of executive control. These studies, therefore, differ in their approaches, the questions they asked and how they interpreted their results. However, none of these studies was a direct replication of any previous study.
An approach some researchers have adopted to examine the veracity of the bilingual advantage claim is to exhaust the issue by administering all kinds of tasks on all kinds of people. In one such study, Paap and Greenberg (2013) examined all possible domains of bilingual executive control with different tasks. Their range of tasks includes 15 different types of task linked to one or the other type of executive control. They found no effect of bilingualism on any one of these tasks. Further, bilinguals were slower than monolinguals on one task. They interpreted their findings saying there is obviously no bilingual effect on executive functions. The participants in Paap and Greenberg study were university students and all had different first languages. Interestingly, the authors suggested that maybe the university students being young adults had already reached an asymptote with regard to their executive control and therefore bilingualism may not additionally add much to it. However, this can’t be true since many studies that have been performed in older adults do show an advantage for the older bilinguals. In any case, Paap and Greenberg did not attempt to test a particular hypothesis but all the hypotheses together. Their approach was, therefore, to exhaust the possibilities of any reinterpretation. However, they recommended that one can keep searching for the bilingual advantage. They suggested the following points be considered by any author who wants to demonstrate the advantage: “(1) identify the specific component(s) of executive processing that should be enhanced by managing two languages, (2) show a bilingual advantage in an indicator of that component across two different tasks, (3) show that the indicators correlate with one another and have some degree of convergent validity, (4) show no differences between the two groups on a pure block of easy choice-RT trials, (5) match the groups on socio-economic status (SES) and (6) minimize cultural differences between the groups.”

Coderre and van Heuven (2014) proposed that if the two scripts of the bilinguals are similar then they need to tackle language control more since script similarity can lead to higher parallel language activation. Therefore, such bilinguals should demonstrate higher executive control than bilinguals with different scripts. They compared German–English bilinguals (same script), Polish–English bilinguals (low similarity) and Arabic–English (no similarity) and found that the same script bilinguals had better executive control, as demonstrated in a Stroop task. The Arabic–English bilinguals had the lowest Stroop interference scores. Although these results are not that straightforward, the idea of whether scripts and their similarity could influence executive control, in general, is interesting. Paap, Darrow, Dalibar, and Johnson (2015) criticised this paper on multiple grounds. Firstly, it is not easy to establish empirically if scripts are similar and, secondly, it is not easy to say which component of executive control was influenced by script similarity. I think these observations are valid to some extent. Further, this effect has not been replicated in other bilinguals.

In summary, there have been many studies that have failed to gain the positive results obtained by others. Some researchers have concluded that there is no such thing as a bilingual advantage while others think we have not yet approached the issue correctly. Some have found null results with children and think their results can be extrapolated to young adults. Yet some others have studied older bilinguals...
and have found them to display cognitive advantage (Bialystok et al., 2004, 2008). There are also studies that have not found positive evidence of superior executive control in older adults (Anton et al., 2016; Kousaie & Phillips, 2012). Whether it is the choice of the right task or the right age, there have now been many replication failures in the field. In the following section I discuss studies that have attempted to replicate the findings with older adults, including studies of patients with neurodegenerative diseases from hospital records. These studies further inform us about whether the bilingual cognitive advantage is sustainable throughout life or is restricted to a certain age group.

4.5 Cognitive Reserve, Bilingualism and Replication Failures

Many studies have shown that the constant practice of bilingualism over a lifespan builds cognitive reserve which then fights against the onset of neurological diseases (Alladi et al., 2016, 2017; Bialystok et al., 2007). The idea is that the practice of bilingualism enhances the cognitive immune system of the brain which delays the onset of diseases such as Alzheimer’s. Of course, there has been both positive and negative evidence for this. But why and how should bilingualism change the key structures of the brain over time? It is well-known that the structure of the brain and connectivity (structural and functional) changes over the lifespan. However, how exactly the change happens in individuals who go through different experiences is debatable. How do the core components of executive control change over time? Figure 4.2 shows the three types of changes that one can hypothesise with regard to the brain’s cognitive control over the lifespan.

Figure 4.2 shows the normal continuum of cognitive performance over a lifetime and its eventual deterioration. Craik and Bialystok (2006) propose that if certain parts of the brain that play a critical role in cognitive control receive much more practice, then the deterioration of their functionality is slower. Sustained practice keeps the structural and functional robustness even when there is age-related decline. Does the practice of bilingualism maintain neural tissue that supports flexibility, monitoring and selective attention into old age? It appears that age-related decline of core cognitive functions such as task switching varies greatly for young and older adults (Cepeda, Kramer, & Gonzalez de Sather, 2001). Inhibitory control declines faster than working memory as we age. Different components of cognition or executive control change differently over time as we age normally (Glisky, 2007).

How do we map the lifespan trajectory of key cognitive functions that bilingualism modulates? This would require also knowing to what extent people practice bilingualism differently as they age. The quantum of practice that a bilingual gets is dependent on the opportunity to actively function as a bilingual in any social context. If the quantum of the practice of a skill (bilingualism) is the key to such neural changes over time, then we must know how differently aged people practice bilingualism. The influence of culture is also not to be overlooked in this calculation since the quantum of use of both the languages in old age is not the same in all cul-
If the quality and type of bilingualism that younger children practice during their developmental years are very different than university-going adults then it is likely that their neural structures are boosted differently. If older bilinguals in certain cultures do not engage in much bilingualism then bilingualism is not going to bestow many benefits to their neural systems. We do not have this kind of comparative data

**Fig. 4.2** Three possible models to explain how cognitive performance changes from childhood to old age. (Craik & Bialystok, 2006)
as of now. What is available are studies that have been on patients with neurodegenerative diseases and correlations with their bilingualism.

The clinical and health implications for the conjecture that multilingualism and bilingualism can reduce the onset of serious disorders is enormous. Different societies and cultures are ageing at different rates. A country with a majority of ageing monolinguals has to bear more costs for their health management if multilingualism could have saved it. Current estimates suggest that by 2050 the population of Europeans aged 60 years or more will be more than 30% of the total population (Leca, 2017). The map given in Fig. 4.3 on the current status of epidemiological data on dementia throughout the world shows that we still do not have data from many continents.

How can we know if bilingualism can delay the onset of neurodegenerative diseases? One method researchers have adopted is to look at the diagnosis time of patients admitted to hospitals. When such patients receive a diagnosis clinicians often collect demographic information, including language data. At times this information can inform whether a patient was bilingual or monolingual, although one cannot be sure to what extent they were an active bilingual. It also is very difficult to get such data from caregivers who may not have interacted with such patients when they were disease free. Importantly, the diagnosis methods of diseases such as Parkinson’s and Alzheimer’s are different in many countries. In countries such as India or China as compared with advanced western countries, many are not diagnosed at once. Therefore, from hospital records, it is not easy to find out the exact

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**Fig. 4.3** Global prevalence of dementia: a Delphi consensus study. (Ferri et al., 2005)
onset of the disease. There have been many studies that have shown that bilingualism correlates with the age of onset of such diseases. However, this age of onset has been different from study to study given the many other practical issues involved and cultural differences in medical diagnosis in many countries. Of course, it could be said that there is no other way you can know the age of onset than from hospital records. But the key issue is how to make sure that when these patients were diagnosed there was a good objective evaluation of their bilingualism.

One factor that can be very decisive in explaining the bilingual cognitive advantage is immigration status. The review by Bak and Alladi (2016) indicates that most studies in the west (Canada) and elsewhere have compared immigrant bilinguals with resident monolinguals. These immigrants often struggle to make a life in a new land and to adjust. This may make them more adaptive to adversity and this could be the reason why they often outperform the monolingual residents on cognitive tasks. Bak (2016) also cite the healthy migrant effect hypothesis (Fuller-Thomson & Kuh, 2014), which suggests that any advantage seen in migrants is not necessarily because of their bilingualism but rather because most often the healthy and most competitive individuals decide to migrate. Therefore, they may already be cognitively superior to the host population who may not have faced many challenges at home. This theory should then predict that when one compares bilinguals who are non-immigrants with monolinguals there should be no group difference. However, as the results show, this is not true (Bak et al., 2014).

How does the migrant status influence our understanding of data related to bilingualism, cognitive reserve and later onset of dementia? Here I discuss a few studies that have been carried out by Alladi and colleagues in India (Alladi et al., 2013, 2016), primarily in Hyderabad, a large multicultural metropolitan city in southern India in which most people speak Telugu as well as Hindi and English. Therefore, most people can be classified as multilingual rather than just bilinguals. Alladi et al. (2013) looked at patient records of people diagnosed with different types of dementias and gathered the case histories of a large number of participants. They also gathered further language data about the patients from caregivers. Their published results show that patients who were bilinguals had a later onset of dementia than monolinguals. This positive correlation may, at first glance, look very rich given the inclusion of records for so many patients. However, a close examination of the data suggests that multilingualism and literacy were confounding variables. It is well-known that in the Indian context, where government clinics are understaffed and provide little cutting-edge diagnosis and treatment, many illiterate people come in for treatment since it is cheap. Further, the data from Alladi et al. does not say what the exact extent of language use by these patients was before they were diagnosed. It is also not clear what kinds of language diagnosis clinicians perform when a patient who has had a stroke and cannot speak much first reports at the hospital.

Bak and Alladi (2016) cite these data to support the idea that these bilinguals were not migrants. Migration has to be understood in a large country like India also in terms of migration from one province to another. Most Indians migrate from their native province to another province (often a large city) for jobs or education and adapt to a new culture. It is very much possible that many of these patients had
migrated into Hyderabad much earlier in life in some sense. In the same review article, the authors criticise the study by Duñabeitia et al. (2014) regarding the validity of the control group. Duñabeitia et al. (2014) did not find any bilingual advantage when they compared Basque–Spanish bilinguals with monolinguals. However, Bak does not find a flaw with the many studies of Alladi et al. that are from India where even defining bilingualism objectively may be a problem given the diverse set of variables that can affect such a decision (literacy, poverty, schooling, multilingualism, cultural factors, etc.). To me, this can be taken as good evidence of selective interpretation of results to foster a point of view. Bak writes “The Hyderabad study provides the strongest evidence to date that bilingualism can delay the onset of dementia, independently of immigration and education”. The problem with this blanket assertion is that Hyderabad is multilingual and has a large population of immigrants from across the country.

It makes sense when a study is replicated with similar kinds of variables. The data in the studies of Alladi et al. were from hospital records of patients in Hyderabad. Is this pattern of results replicable in other southern Indian cities? Ellajosyula et al. (2015) examined case histories of patients from a Bangalore, a southern Indian city. They separated the patients into those who had dementia, Alzheimer’s disease and frontoparietal dementia. They also looked at whether the patients were monolinguals, bilinguals or multilinguals. To their surprise, they did not find any effect of bilingualism on the age of onset of the disease. Interestingly, many who have cited Alladi et al. in the context of cognitive reserve in the Indian context have not cited this study. I think this is a very close replication of the approach Alladi et al. (2013) have taken in most of their studies. Reflecting on their null results, the authors write that there are a host of factors other than bilingualism that can influence cognitive reserve. It is very difficult, at least in the Indian context, to link bilingualism with any cognitive reserve.

The whole point in such studies rests on the critical fact of when the patients were diagnosed (after what point in time after the onset of symptoms) and what went into the initial hospital records. This is important since it becomes the primary instrument for all later comparisons in such studies. It is clear that countries and cultures differ with regard to when patients are formally diagnosed. Many patients who may have dementia may not go for a diagnosis at all for a very long time. The other critical question is what can be known about the level of bilingualism from such data. If one says that the level of bilingualism is not a significant factor in establishing the conclusions then it may be problematic. Many studies show that language use has an important influence on executive control (Verreyt et al., 2016).

Dementia diagnosis has been very diverse in India (Wadia, 1992). One cannot be very sure that government hospitals in India provide a first-rate diagnosis facility, and therefore the data that one mines years later to seek correlations can be problematic. This could be the case for most underdeveloped or developing countries. Prince (1997) remarks that extent of industrialisation, quality of life, economic status and other environmental factors are important in the prevalence and diagnosis of dementia in different cultures. It has been established that different diagnosis criteria could lead to different evaluation of age of onset (Erkinjuntti, Østbye, Steenhuis,
At this point in time, such data for India are not available. It is also not clear at what age the Indian ageing population in general shows signs of dementia. The prevalence of dementia among the tribal population, urban dwellers and people in rural regions is vastly different (Raina et al., 2014). Therefore, it is not easy to separate out only bilingualism from the many factors that are very specific to India.

Many studies have not replicated the cognitive reserve effect seen with western populations. Lawton, Gasquoine, and Weimer (2015) examined whether bilingualism was the factor that differentiated the age of onset of dementia in patients. They did not find any difference between bilinguals or monolinguals as far as the age of onset was concerned. In turn, they also pointed out that most researchers who have found correlations between bilingual status and age of onset of dementia have confused the age of clinical diagnosis and the first report of symptoms. Clare et al. (2016) compared older adults with Alzheimer disease with healthy adults to check for the effect of bilingualism on the age of onset of the disease. They did not find any such effect. They suggested that the nature of bilingualism and context of the participants may have played a role in null effects. What about the use of reading and writing knowledge apart from spoken language use on age-related cognitive advantage? Crane et al. (2010) took second-generation Japanese–American older bilinguals and collected data on their reading–writing skills. Importantly, these bilinguals were not immigrants in the conventional sense. They found that the rate of cognitive decline was not correlated with bilingualism.

I wish to make a contrast between the research that has used patients’ hospital records for post hoc theorising on cognitive reserve and bilingualism and the research that directly compares older bilinguals (mostly normal participants) on conflict or attention tasks using behavioural and neuroimaging methods (Fig. 4.4). These studies (Abutalebi et al., 2015) show that older bilinguals at times outperform older monolinguals on conflict tasks. However, as is the case, researchers have not always been able to replicate the findings across languages and cultures. For example, considering the claims of (Alladi et al., 2013) on the links between bilingualism and onset of dementia in Hyderabad, Padmanabhuni et al. (personal communication) examined how older bilinguals from Hyderabad perform on a host of demanding conflict and attention tasks. They took language proficiency as the variable to further correlate with performance on attention tasks. Language proficiency has been shown to predict performance on executive control tasks in younger Indian bilinguals (Singh & Mishra, 2012, 2013, 2015, 2016). Unlike de Bruin, Bak, and Della Sala (2015), who think that the quantum of use of L2 need not influence the outcome on conflict or executive control tasks, Mishra and colleagues argued that it is language use that should, if at all, correlate with executive control tasks. Further, highly proficient bilinguals (L1 Telugu, L2 English) should indulge in bilingualism more. Therefore, proficiency in both the languages (in this case primarily in L2) should allow the bilingual to switch and shift more often than the less proficient ones. They administered the Flanker task, Wisconsin card sorting and verbal and non-verbal Stroop tasks as well as a host of objective and subjective language proficiency evaluation tasks. Their participants had studied in schools with English as the
medium of instruction and there was homogeneity with regard to their usage history of L2. Schooling can be an important variable in the Indian context since many bilinguals acquire knowledge of English much later in college or university if they have not studied in an English medium school. The study was designed to find out whether L2 proficiency should predict performance on these tasks. This kind of data will also fill the gap in informing about bilingual advantage in healthy older bilinguals.

Gasquoine (2016) reviewed the literature and found that a host of variables that can influence results in the cognitive reserve domain have not been taken into account. The author was referring to collecting objective data from people with the same ethnic and cultural backgrounds. He also comments that unless we try to sort out the differences in behavioural results, we should not jump into the brain. Neuroimaging data and differences may not be informative unless we know if the behavioural data have any consistency. However, authors such as Abutalebi and others who have consistently examined neuroimaging data either to support the cognitive research or the advantage theory think that behavioural data could be secondary. Behavioural and neural data could speak about very different processes altogether. It is worth looking at the few exchanges between Gasquoine and Alladi et al. on the issue of replication (Gasquoine, Weimer, & Lawton, 2016). Bak and Alladi (2016)) think that replication failures can be understood if we take into account our attitude towards bilingualism. The national attitude towards bilingualism could influence how we collect our data. The author is of the opinion that we should take community-
based data as opposed to collecting decontextualised case reports from clinics. They think that the sensitivity of people in different cultures and nations could influence whether bilingual advantage is seen or not in that particular culture.

If bilingualism is delaying the onset of dementia then it should have some influence on the current estimates of its incidence (Albanese, Guerchet, Prina, & Prince, 2016). Albanese et al. (2016) point out that it is not clear if the statistical estimates of incidence are changing. I wonder how this information may affect our current link between bilingualism and the diagnosis of different types of dementia. Further, the incidence rate varies greatly between industrialised nations and low-income countries. For example, in a survey of dementia in the city of Calcutta (Banerjee et al., 2017) it was seen that the prevalence of dementia is different for low educated people.

I think it is very problematic to make a case for bilingualism and cognitive reserve in the Indian context. The main reason is the lack of monolingual control groups without compromising variables such as socio-economic status and literacy. There is much epidemiological research from the medical community that shows how diverse dementia prevalence is in urban and rural areas (Das, Pal, & Ghosal, 2012). Secondly, since much debate in this field will depend on what the primary assessment was when the patient checked in, it is not clear if all diagnosis instruments contain questions on bilingualism. For example, a dementia diagnosis instrument developed for patients in southern India (Stanley et al., 2009) does not include many questions on language assessment. It is also unclear from the studies of Alladi et al. (2013) what the extent of language assessment was when these patients were first diagnosed. Further, assuming that bilingualism does indeed influence neural tissue loss and create a cognitive reserve, we should see a longitudinal delay in age of diagnosis. However, there is no such data that would allow us to look at this issue with a broad perspective. The study of cognitive reserve in older people will probably be more legitimate where you have clearly defined bilingual and monolingual populations. However, the other alternative I propose is to take language proficiency into consideration and see if those who used language more got the disease much later than who spoke less. This will not require a monolingual control group, which anyway does not exist in urban India from whose clinics much of these case records come.

4.6 Summary

In a very uncharacteristic manner, I devoted this whole chapter to studies that have not replicated the bilingual cognitive advantage effect. These studies have led to much discussion in the field and many questions. Of course, the link between speaking two languages and neuroplasticity, though spectacular, is not easy to establish. Methodologically sound research with appropriate controls could unravel the actual relationship. In the absence of direct replication, it is not easy to know why a study could not replicate the original results. In this chapter, I showed that these null or
negative results are of many types themselves. For example, one type of study denies any advantage altogether. Other types of study point out specific conceptual or methodological flaws that future researchers can incorporate. The key question is in whom is the advantage expected? At this point in time both advantage and no advantage positions have their own followers. The issue of publication bias is more general to many scientific fields and not specifically to bilingualism research. While it is legitimate to replicate scientific findings, the replications themselves should be methodologically sound.

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Chapter 5
Neuroscience of Bilingualism

5.1 Cortical Representation of L1 and L2

What is the hypothesis behind the suggestion that acquisition of a second or third language should influence the neural structures and modify them? Neurolinguists like Michel Paradis (2004) and neuropsychologists like Henry Hecaen (1972) had assumed that linguistic theories and neural processing informed by brain imaging should be compatible. Language structure should be able to modify the neural strata. Of course, the functional significance of language to the brain was first made explicit by Lenneberg (1967). Paradis (2004), in his book A Neurolinguistic Theory of Bilingualism, emphasised taking linguistic processing seriously to account for neural data. This was to seek a one-to-one correlation between linguistic complexity and neural activation. Data from bilingual aphasics was important in constructing such neurolinguistically informed theories of bilingualism. In that tradition, bilingualism was not to be merely thought of as cognitive modelling of two languages, but how the acquisition of one additional language could influence the existing neural networks that are currently serving the first language, and how the structural similarities or differences between the two languages could impair or facilitate the acquisition and in turn neural activation. Many neurolinguistic studies have examined whether the first and the second languages are represented in separate networks or a single network controls them. The separate network idea seems intuitive. However, it is also equally likely that the same network accommodates the second language as one learns it. The accommodation theory assumes that the network used for the first language gradually adapts to the second language depending on the necessity. Perani and Abutalebi (2005) found that it is the same network that shows activations of both first and second language processing. If the speaker is a learner and has less fluency in the second language then the activations will be higher. As proficiency develops, the network adjusts itself. Therefore, the age of second-language acquisition, fluency and proficiency influence the activations. It is important to note that these variables also influence executive control during language management.
How strong is the neuroimaging evidence supporting a bilingual–monolingual structural difference? Garcia-Penton, Fernández García, Costello, Duñabetia, and Carreiras (2015) raise issues with the methodology many have adopted in these brain imaging studies. One major problem is the heterogeneity of the bilingual population with regard to different variables. Secondly, the authors argue that different researchers have used diverse methods for analysing the brain imaging data. Further, very few brain imaging studies have been on non-western bilingual populations. More recently, Das, Padakannaya, Pugh, and Singh (2011) studied structural differences between Indian bilinguals and monolinguals. In India, these bilinguals are also bispensal, which can make matters complicated. Nevertheless, these authors have reported differences at the level of microstructures as a function of bilingualism.

Cortical representation of second language (L2) is an outcome of both age of acquisition and the mastery attained in that language. However, neurolinguists also suggest that if the languages are closer to one another in terms of structure or family resemblance, then L2 cortical representation should be different. Using brain imaging, Perani et al. (1998) examined Italian–English and Spanish–English bilinguals who were both high proficient in L2 but had acquired these at different timepoints. The authors explored whether the age of acquisition and proficiency in L2 influence cortical activations pertaining to L2. The study showed that there are both similarities and differences between native language (L1) and L2 representation in both these bilinguals. Thus, there were no special networks devoted to L2 processing for such bilinguals. L1 and L2 may not have dedicated networks that are structurally separate, but different groups of neurons may process L1 and L2 depending on the age of acquisition and proficiency. In a recent fMRI (functional magnetic resonance imaging) study, Xu, Baldauf, Chang, Desimone, and Tan (2017) studied Chinese–English bilinguals on an implicit reading task. The main aim was to see which brain areas are active for Chinese and English separately. Figure 5.1 shows the main highlights from their study where different cortical areas show specific activations for L1 and L2.

The authors performed multi-voxel pixel analysis and found that within the same cortical structures different populations of neurons are involved in the processing of L1 and L2. Therefore, functional independence is not related to the distinct structural sites or networks of areas but the population of neurons. Their task used single words that were either real words or were false fonts. The problem with using single words is that they do not bring in the complexity of using connected speech. However, based on their findings the authors make some interesting remarks about language control. They suggested that functional separation is necessary if bilinguals have to control and shift between the two languages. If one holds the assumption that languages are represented in a single network, the question of control may not arise. Abutalebi and colleagues have shown in many fMRI studies (e.g. Abutalebi, Cappa, & Perani, 2001; Abutalebi, 2008) structural independence between L1 and L2 in the brain.

At least for sequential bilinguals, the order of acquisition of the two languages plays an important role in their later proficiency. It is well-known within the neurolinguistic literature that the left frontal and temporal areas are recruited for process-
ing the first language (Perani et al., 1996). What happens when someone learns a second language? In an early brain imaging study with French–English bilinguals, Dehaene et al. (1997) found that while the left hemisphere was active for processing the L1 as the participants listened to stories, the right hemisphere was active for L2. This led the authors to suggest that the well-known traditional language areas of the left hemisphere are for the L1 and when L2 is acquired newer areas within the right hemisphere are recruited. More direct evidence of language representation in the brain has come from studies where cortical recording has been done with patients undergoing surgery. In such a study, Lucas, McKhann, and Ojemann (2004) recorded from cortical sites in patients undergoing surgery. The authors reported that although L1 and L2 processing could be functionally separate, there were also many shared sites in both left and right hemisphere areas. Language areas in the left hemisphere were exclusive to the processing of L1 while posterior and anterior areas were recruited for L2. This suggestion is very different from that of Xu et al. (2017) discussed earlier.

However, other results do not support this structural and functional separation view between the two languages. Abutalebi et al. (2001) reviewed the bilingualism
and neuroimaging literature and suggested that language proficiency and language exposure are important variables that influence the cortical representation of language in bilinguals more than the age of acquisition. These variables are more related to the attainment and practice of skills in the bilingual. According to Abutalebi et al. (2001), as proficiency increases, a common brain network is used for both the languages. Proficiency has also been shown to modulate executive control in bilinguals (Singh & Misha, 2012). It makes sense to assume that as a bilingual grows into a fluent speaker of the second language, the brain networks that were exclusively used for L1 start adapting. Adaption here refers to the recruitment of cognitive systems to process the language in question. This theory will imply that bilinguals who may have an earlier age of acquisition but do not have current proficiency in L2 will not have the necessary neural structures for easy adaptation.

Grosjean’s provocatively titled article “Neurolinguists, beware! The bilingual is not two monolinguals in one person” captured the then-current opinions of the field (Grosjean, 1989). Grosjean’s main thesis concerned the idea of language mode: a bilingual person could set themselves into different language modes. Language mode is also induced by the environmental context which can shift between monolingual to bilingual. Grosjean defines language mode as “the state of activation of the bilingual’s languages and language processing mechanisms at a given point in time” (Grosjean, 2001). I am bringing the issue of mode here to link such selective preference of context and the issue of structural separateness. Ultimately, one has to account for how bilinguals who have to dynamically deal with different interlocutors and shift between linguistic domains manage this if the neural separation is strict. One cannot say that the structural separation of language in the bilingual’s brain has no impact on how bilinguals manage the two languages. Bilinguals often voluntarily shift between modes. How does the neurolinguistic theory of bilingualism connect to this issue? Depending on the nature of processing one may expect either a shared or a separate neural mechanism for the two languages in a bilingual. Marian, Spivey & Hirsch (2003) suggest that a shared neural network is active for parallel language activation and two distinct networks may be in use for processing lexical structures. They studied parallel language activation using eye tracking. The mode is relevant here as a concept since bilinguals can be said to shift between the modes (when they shift between languages). Therefore, corresponding neural activations could be dependent on the modes of processing. Thus, the neurolinguistic concern about L1 and L2 representations are legitimate. However, as is evident, for every result that finds separate neural structures devoted to different languages, there is a paper that does not report this.

5.2 The Switching Bilingual Brain

One of the most defining attributes of bilingualism is language switching. Many neuroimaging studies have focused on language switching and how this may sculpt the brain networks (Abutalebi & Green, 2007; Hernandez, 2009; Luk, Green,
Abutalebi, & Grady, 2012). If bilinguals switch between languages all the time, then this must make them good switchers in general. They should be able to switch well with a minimal cost between two non-linguistic tasks also since switching as a mechanism is not restricted to just languages. Non-linguistic task switching studies show that such switching has a cognitive cost (e.g. Arrington & Logan, 2004; Rogers & Monsell, 1995). Switching between two tasks creates constraints with regard to maintenance of task rules; for example, doing a Stroop or a Simon task interchangeably. These tasks demand different rules to be kept in mind for successful switching. Alternatively, one can perform task switching with the same stimuli while shifting attention. For example, someone is shown the picture of a cat and asked to name it ‘cat’ on one trial and then say ‘animal’ in another. This shifting between two responses will amount to task switching. To do this well one would be required to also switch selective attention from trial to trial, which will require cognitive control. Does bilingualism lead to better neural efficiency in non-linguistic task switching? Or even, alternatively, does training in non-linguistic task switching effect stitching between languages?

The switching hypothesis links both linguistic and non-linguistic control to the same neural system. Therefore, before accepting the proposal that bilinguals use cognitive control to reduce switch cost, one has to accept that both linguistic and non-linguistic switching is governed by the executive control networks. Since bilinguals switch a lot, the neural networks supporting switching should be very efficient. Neural networks being efficient may manifest in hypo-activation or less engagement of relevant brain areas. Most commonly, researchers give either a linguistic or a non-linguistic switching task and see if brain activations for monolinguals and bilinguals differ. In many instances conflict tasks such as the Stroop are also used to see if the anterior cingulate cortex (ACC) is active during conflict management. The Stroop task can be verbal or non-verbal and one can compare the two for knowing the processing similarities and differences. Therefore, researchers either study task switching or conflict resolution. Interestingly, for both of these the ACC has often been implicated (Abutalebi & Green, 2007; Johnston, Levin, Koval, & Everling, 2007; Liston, Matalon, Hare, Davidson, & Casey, 2006). However, switching and conflict as causes of language management have their own distinct theories—they don’t offer the same theoretical account. Abutalebi and Green (2007), in their neurocognitive model for bilingual language control, proposed that the dorsolateral prefrontal cortex (DLPFC) controls executive functioning, the anterior cingulate cortex is involved in inhibition and the caudate nucleus is involved in the lexical selection and goal planning. Since switching involves both control and lexical selection, all these areas are involved in switching.

We often assume that all kinds of bilinguals more or less switch. However, that is simply not true since the quantum, and nature of switching (into L1 and into L2), differs widely from culture to culture. Switching is contingent on the habits of the bilingual speech community. Often researchers do not provide such data regarding the quantum of switching. In Grosjean’s conceptualisation of language mode (Grosjean, 2001), the frequency and nature of switching depends on the bilingual status of the speaker and hearer and also mode. For example, two bilinguals who are
primarily talking in one language may prefer to switch to the other language at times. Thus, for such bilinguals, the quantum of switching may be much less. Many bilingual societies may be of this sort in which switching into the non-dominant language may be less. Language mode could be a major variable that can influence switching. These facts should be kept in mind when interpreting brain imaging data related to switching in bilinguals.

An overwhelming range of data have shown that switching deliberately or when instructed leads to cost. The cost is understood to reflect contingencies related to adjustments with task mapping rules as, for each task, a certain response mapping rule is to be activated fresh. If for successive trials the rules don’t change then there is no such cost. Does preparation help one to avoid the switch cost? Does context facilitate switching? Suppose the agent is informed ahead that there may be a possible switch in a certain trial in a block of trials. One may assume that this preparation may make the agent more flexible and there won’t be a switch cost. However, it appears that even when attention has been shifted to the other dimension of the stimuli for an imminent switch, there is still switch cost. This was recently shown by Elchlepp, Best, Lavric, and Monsell (2017) in a task switching study. The subjects were asked to switch between identifying the colour of a letter or whether its type was “consonant or vowel”. On some trials, they were alerted about an upcoming switch. Along with this, the frequency of types of trials was varied. When certain trials are too frequent this can induce prediction and higher surprise in the other less frequent trials. Even in this case, the authors observed switch cost. There are many other dimensions to switch cost and the factors that can modulate this in experiments. For example, Kleinman and Gollan (2016) recently showed that when object naming is conducted within a context, speakers do not show any switch cost. This was in contrast to most studies where participants are asked to name isolated objects based on an instruction.

The most important aspect of switching in bilinguals is that it is essentially a voluntary mechanism. When bilinguals feel the need to change language, they switch. Often interlocutors influence these language switches. Unfortunately, the overwhelming number of studies on bilingual language switching have used the cued naming paradigm (Meuter & Allport, 1999). One can, of course, argue that bottom-up stimuli such as even interlocutors’ faces can be considered to induce cued naming. However, bilinguals use top-down cognitive control to switch between languages. Unless one is clear about this mechanism, it is not possible to understand how bilingualism is linked to cognitive control. The number of studies that have used voluntary naming as a paradigm is limited. I review them elsewhere for other reasons but here it suffices to say that when asked to choose languages voluntarily, bilinguals face the dilemma of choice. Choosing between any two tasks voluntarily poses a specific change for cognition. Nevertheless, few studies have shown that bilinguals often end up choosing the language they are dominant in when asked to choose voluntarily. I am concerned that our current knowledge about the neural basis of bilingual language switching does not include voluntary language switching. We do not know what neural structures support such voluntary switching in bilinguals.
Switching and shifting between task sets fluently calls for executive control. What sort of neural data do we have about the executive control that is exercised in the bilingual brains? Again, to reiterate, executive functions are made up of components such as inhibition, monitoring, selective attention and flexibility (Miyake et al., 2000). Different brain networks are apparently responsible for these functions. The key question is whether bilinguals and monolinguals use similar or different brain networks when they perform executive control tasks? Further, do bilinguals use the same networks for tackling both linguistic and non-linguistic demands in tasks that have conflict? Interestingly, the brain imaging data that exists so far on bilinguals and monolinguals present a conflicting picture. It is not clear if hypo- or hyperactivation is what we should be looking for in the brain networks of bilinguals when compared with monolinguals. Pliatsikas and Luk (2016) reviewed the fMRI studies on bilinguals where executive control was under investigation. Evidence suggests that both bilinguals and monolinguals show similar activation of the ACC when they perform the Stroop task (Mohades et al., 2014). As for the Simon task, the caudate nucleus was shown to be involved in conflict resolution, without much difference in activation between bilinguals and monolinguals (Mohades et al., 2014). Therefore, it is not clear whether the ACC or caudate nucleus or some other area is involved in conflict resolution. It is possible that these tasks demand different types of control mechanisms.

Luk, Anderson, Craik, Grady, and Bialystok (2010) used fMRI to examine whether bilinguals and monolinguals use brain networks differently when they did a conflict task (Fig. 5.2). They used a conventional flanker task to see how participants inhibit a response. Additionally, they were also interested to see whether they can suppress a response altogether. To this end, they added a no-go component to the task. Here, the instruction was to refrain from any response when it was an incongruent trial. The theoretical distinction was between ‘interference suppression’ and ‘response inhibition’. Both bilinguals and monolinguals showed activation of the inferior frontal areas bilaterally and also some subcortical areas. Bilinguals additionally used a more extensive area. This can only be understood if we assume that extensive language management in bilinguals has trained them to use more networks for response inhibition and suppression. Olsen et al. (2015) compared grey and white matter volumes in lifelong bilinguals and monolinguals. Bilingual brains showed more frontal lobe white matter than monolinguals. Further, while older monolinguals had decreasing temporal lobe white matter volume this was not the case with the bilinguals. When the authors administered a Stroop task, frontal lobe volume correlated with performance on Stroop task. Such data suggest that lifelong bilingualism fundamentally alters the structure of the cerebral cortex, albeit at specific sites. These sites are responsible for executive control and other higher order mechanisms. Therefore, the argument is that it is bilingualism which brings such profound changes in the brains. This has been called ‘cognitive reserve’, which is seen in older bilinguals. Although how exactly the practice of bilingualism modulates cognitive reserve remains debated.
There is enormous interest now in cognitive neuroscience to explore resting state neural data. The key question is whether bilingual and monolingual brain networks differ significantly when they are at rest. Resting state fMRI data tries to look at functional connectivity inherent in key brain areas when there is no explicit task (Biswal, Zerrin Yetkin, Haughton, & Hyde, 1995). A key question is whether experience-induced neuroplasticity modulates resting state functional connectivity in bilinguals.

Functional connectivity between one or more brain regions shows temporal dependency among them (Friston et al., 1995). Use of graph theory and other statistical methods on continuous brain images of different regions reveal whether certain brain areas are functionally connected during tasks (van den Heuvel & Pol, 2010).

Fig. 5.2 (a) Brain scores, which represent the degree to which brain activity co-varies with each condition, and (b) brain regions. Monolinguals and bilinguals showed contrasting patterns of activation for the congruent and incongruent trials but had similar activity in the no-go trials. (Luk et al., 2010)
Analysis of the resting state networks can suggest how the brain consolidates the experience and prepares for future events (Buckner & Vincent, 2007). The default mode networks are brain regions that show deactivation during tasks but not when there is no task. The default mode network may comprise several brain regions such as the frontal or parietal regions. The network has been proposed to be involved in episodic memory processing (Buckner et al., 2005). What is important is to link these networks to their cognitive significance.

Bilingualism may significantly shape and modify long-range functional connectivity among important cortical and subcortical areas responsible for language and general executive control. With more experience and ageing, these neural changes become prominent for monolinguals and bilinguals. Figure 5.3, from Grant, Dennis, and Li (2014), shows that for bilinguals the connections between frontal and parietal areas remain strong as they age. However, for monolinguals, these connections weaken and only depend on the frontal areas.

The practice of bilingualism over the lifespan thus can maintain the functional connectivity of the brain into old age. Stocco et al. (2014) have further suggested a key role of basal ganglia in strengthening this functional connectivity among neural regions. Since for the bilinguals language switching involves top-down cognitive control, the prefrontal cortex receives multiple signals from other brain regions. Continual switching and shifting also enrich the white matter of the brain Luk et al. (2012). The adult brain changes continuously with regard to experience. For example, Ericsson et al. (2011) showed that the cortical volume of hippocampus changed significantly in adults following aerobic training and also when interpreters were trained for 3 months in handling multiple languages. The authors, however, make the important observation that any such structural changes at the microstructural level of the neural tissue do not necessarily translate into behavioural achievements. Structural changes in the brain may also occur because of many other environmental factors (Lövdén, Wenger, Mårtensson, Lindenberger, & Bäckman, 2013). The key question is if the structural and functional changes as a result of bilingualism are

![Fig. 5.3](image_url) The ageing bilingual vs. monolingual brain. In monolinguals, ageing leads to increased reliance on frontal areas, whereas in bilinguals reliance on posterior areas increases with age. (From Grant et al., 2014)
sustained over time so as to enhance cognitive capabilities beyond language control in a permanent manner. The type of bilingualism one practices (more vs. less switching) may induce neuroplasticity differently. Context and language proficiency could be key variables that may explain the differences one sees between bilinguals and monolinguals in neural data (de Bruin & Sala, 2016).

Cachia et al. (2017) examined the development of ACC sulcation in bilinguals and monolinguals. Participants also performed the Flanker task as a measure of executive control. The idea was to see whether the changes in the ACC sulcation pattern are linked to performance of the executive control task. The sulcation of critical areas changes over time because of experience and maturation. The ACC sulcal variability predicted performance on the Flanker task in bilinguals. Such data demonstrate that bilingual experience and conflict management brings marked structural changes to key brain regions. With sophisticated brain morphometric analysis, it is possible to understand how bilingualism modulates the changes in brain networks as experience accrues. Ranjan, Mishra, and Singh (2017) collected neural activation data from Indian bilinguals. They measured diffusion tensor imaging data to study the cellular microstructure of the white matter tracts. The data revealed a correlation between changes in the microstructures of the right superior longitudinal fasciculus and language proficiency.

Garcia-Pentón et al. (2015) reviewed the brain imaging literature on bilingual–monolingual difference and found some methodological anomalies. They suggested that if correct methods are used and samples are taken carefully then brain imaging data have the potential to reveal many insights. They also indicated that brain imaging data could reveal the true nature of the advantages that bilingualism bestows. Commenting on this article, Paap (2016) wrote the following in his abstract:

This commentary on Garcia-Pentón, Fernández García, Costello, Duñabetia, and Carreiras [2015. The neuroanatomy of bilingualism: How to turn a hazy view into the full picture. Language, Cognition and Neuroscience] suggests that their review may have understated the inconsistencies among studies comparing the neuroanatomy of bilinguals to monolinguals. If their recommendations for better and more consistent methods, larger sample sizes, systematic investigation of various types of bilingualism, and more longitudinal studies were followed the structural picture should become clearer. The main thrust of the commentary is that this clearer picture of the structural changes caused by bilingualism is unlikely to inform the debate over bilingual advantages in executive functioning because: (1) there is no direct mapping between brain function and cognitive function, (2) interpretation of structural differences must rely upon unambiguous alignment with behavioural performance advantages, and (3) the current body of evidence supports the conclusion that either bilingual advantages do not exist or that they are restricted to very specific and undetermined circumstances.

I quote this abstract in full as it is important. Paap denies the existence of any links between bilingualism and cognitive advantage. Whether the method of enquiry is brain imaging or behavioural is irrelevant to him. Further, he says that brain data and behavioural data are too different to be correlated. “There is no direct mapping between brain function and cognitive function” is too radical a statement to make. Contemporary cognitive neuroscience exists on this presumption that neural activations correlate with cognitive processing. If this is not true, all brain imaging data would be meaningless.
5.4 Cultural Neuroscience and Bilingualism

Although we study the brain and cognitive functions as if they are culture-neutral, the fact is cultural forces shape them a great deal. Are all bilinguals similar across different cultures? How do cultural forces unique to different cultures modulate bilingualism and its effect on cognitive control? Of course, any theory aims to be culture-invariant while taking into account any parameters related to cultural diversity. Experimental work in cross-cultural psychology and social cognitive neurosciences have been looking at culture-specific effects (Park & Huang, 2010). The key question is whether we are able to replicate the findings related to management of conflict, response inhibition, response suppression or monitoring with bilinguals that come from diverse cultures. The assumption is that cultures influence how different bilinguals use control mechanisms for their language management in their unique ways. Thus, we need more cross-cultural data on both neural and behavioural effects. Presumably, different bilinguals develop different types of control mechanisms depending on the language context they have encountered across their lifespan. In an extensive review of the evolutionary origins of executive functions and neuropsychological dysfunctions, Ardila (2008) observes that cultural influences on the development of executive functions can’t be overlooked. Bilingualism is intriguingly linked to cultural habits of speaking and listening. If this is the case, then one must find cultural variables that interact with bilingualism to sculpt neural structures that tackle various control mechanisms. One would wonder how, if in a certain culture people are not trained to see a conflict in every incongruent scenario, they are going to perform the Stroop task? For example, different studies have shown that holistic and analytic cultures influence the attentional mechanisms (Hedden, Ketay, Aron, Markus, & Gabrieli, 2008; Masuda, Gonzalez, Kwan, & Nisbett, 2008). Here I examine how culture modulates different systems of executive functioning.

Hedden et al. (2008) examined whether brain activations in people from eastern and western cultures differ when they perform a visuospatial task that involves absolute or relative judgment. Absolute judgment is when we just focus on the object as such without the context. Relative judgment includes contextual assessment. The key idea was to see if those from East Asia consider contextual information more while they judge central figures than do westerners who only pay attention to the object in question. When people performed the task that was incongruent with their cultural habits (East Asians performing the absolute judgment), neural activity in frontal and parietal areas was higher (Fig. 5.4). This means greater neural resources were necessary for this task for these individuals. The authors speculated that cultural habits of attention deployment could influence the neural mechanism. Han and Northoff (2008) reviewed cross-cultural neuroimaging studies on higher-order and lower perceptual processes. The blend of social–cognitive neuroscience and cross-cultural psychology has opened the possibility of finding both culture-variant and -invariant neural mechanisms of cognition. Han and Northoff (2008) raise an interesting question with regard to cultural variables being constitutional or modulatory. If they are constitutional, then certain brain regions that are known otherwise to support, for example, attentional processing may not show activity if attentional
engagement is qualitatively different in such people. If they are modulatory, then such brain regions in people from different cultures will show activity to different degrees. Current data do not allow us to speculate on these fine-grained effects.

The other interesting questions which Han and Northoff (2008) raise include the impact of variables such as illiteracy and ageing. Illiteracy is still prevalent in many cultures. Further, cognitive decline due to ageing happens differently across cultures. These variables could influence results independent of factors such as bilingualism. This angle has not been explicitly pursued in many studies on older bilinguals. Although many have used retrospective data from hospital records, the tendency has been to select participants after controlling for these variables, whereas these very variables could have influenced the very practice of bilingualism (vis-à-vis attention control) in participants in their premorbid stage. Han et al. (2013) introduced the term cultural neuroscience (CN) to refer to the research activity that is conducted using brain imaging techniques on different cultural groups. CN approaches try to predict specific neural and behavioural effects in specific people considering cultural variables inherent in that culture. Han et al. (2013) wrote that

CN actually has a nonreductionist view of the relationships between formative biological and cultural properties of the human brain. As previously noted, CN studies aim to elucidate neuroplastic and culturally generated processes. This is fundamentally at odds with cultural

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**Fig. 5.4** (a) Sample trials. In the relative-instruction condition, participants judged whether each box and line combination matched the proportional scaling of the preceding combination; in the absolute-instruction condition, participants judged whether each line matched the previous line, regardless of the size of the accompanying box. (b) Difference scores for the relevant brain regions. Participants exhibited greater activation in culturally non-preferred tasks—Americans in the relative task and East Asians in the absolute task. (Hedden et al., 2008)
essentialism and hard-wired biological determinism. CN researchers generate specific hypotheses about neurocognitive processes grounded in both behavioural findings from cultural psychology and brain imaging findings from cognitive neuroscience. These hypotheses limit the brain regions under investigation and predict specific patterns of cultural group differences and individual differences in brain activity. Thus CN research does not study culture as a set of biologically determined predispositions/constraints that can be used to rigidly categorize collections of people. Instead, the CN approach emphasizes the flexibility of the human brain that enables humans to adapt to sociocultural environments (p. 351).

Thus, what we study as cognitive systems with controlled psychophysical tasks in the laboratory are already under cultural influence. This may also undergo shift when people migrate from their native culture and adapt to another very different culture. This has an important bearing on studying bilinguals who settle in another culture in which they are studied.

For example, consider Chinese–English bilinguals who study in the USA. The native culture of these bilinguals has already sculpted their attentional and perceptual system differently towards a holistic mode of operation. They are not going to look at the visual stimuli and act similar to, for example, Americans who are known to process more objectively. Of course, one can say that since these bilinguals have stayed in the USA for some years, their cognitive system must have undergone changes. Han et al. (2013) ask this very question and suggest that neuroimaging studies should be done in immigrant adults to know how coming into a new culture modulates their core brain functions. At this point, there are only cross-sectional studies and no study has followed people longitudinally as they move across cultures using neuroimaging methods. Given this backdrop, it is possible that such participants’ performances on attentional tasks are going to be different.

Pornpattananangkul et al. (2016) compared Americans and Japanese–Americans living in the USA with the Japanese living in Japan on a go-no-go task in an fMRI paradigm. Brain activity showed that the activity of left inferior frontal gyrus (L-IFG) correlates with cultural groups. The native Japanese who were in Japan showed the strongest activity of the L-IFG. The authors also asked participants for their subjective responses on their daily behavioural consistency. This kind of data can reveal how individuals view their actions and their overall consistency. How does someone think he or she applies inhibitor control every day in different real-life scenarios otherwise? Participants with a high level of self-endorsement of behavioural consistency also showed higher activity of the ACC. These data show that inhibitory control could differ across cultures. Furthermore, qualitative data in correlation with experimental data could reveal an inhibitory control profile of a participant.

Imagine bilinguals from two different cultures who are undergoing brain imaging for a task that involves visual perception. It is possible that bilinguals in the eastern cultures take background interlocutors into consideration when they are planning their language for the focal interlocutor. However, bilinguals in the western countries will solely decide the language for the focal interlocutor who is in front of them even if there are other interlocutors in the background. Green and Abutalebi (2013) refer to the ecology of bilingual language control. This ecology is obviously related to patterns of switching and shifting embedded within a culture and sociolinguistic norms of speaking and interacting. One of the central claims of
the adaptive control hypothesis is that certain bilinguals switch more than others depending on their context. Secondly, bilingual speakers choose their language (thus inhibiting the other) once they know who their interlocutor is. Is this universal across cultures? Although patterns of switching have been studied in some cultures, there are few data available on how bilinguals control their languages with regard to their interlocutors across cultures. I raised the issue of figure-ground perception in interlocutors, which is an implication of the cross-cultural psychological work on attention and visual perception. However, language selection in a given context is far more a critical and top-down mechanism than visual object perception. Studies have established that faces do trigger linguistic activations (Zhang, Morris, Cheng, & Yap, 2013). Therefore, such visual cues, whether they are in the foreground or background, will exert influence on the language selection mechanism. Cultural forces that act in the attentional system should also influence much of the decision pertaining to language control.

Some bilingualism researchers have explored whether bilinguals consider cultural associations during language planning and control. Faces, for example, reflect ethnic and cultural attributes. Recognising a face is also recognising the cultural ethnicity of the individuals. A key question is do bilinguals use this kind of knowledge for their language control? Li, Yang, Scherf, and Li (2013) presented Chinese or Caucasian faces and tracked neural activation in Chinese–English bilinguals. They asked people to name objects either in Chinese or English and simultaneously faces were presented that were either congruent or incongruent with the language to be used for naming. The behavioural data showed facilitation when the language for naming matched with the ethnicity of the face. Interestingly, the brain imaging data showed that for incongruent conditions, there were no significant frontal, ACC or parietal activations. These areas have been shown to be highly active for conflict suppression. Rather, the data showed activation in these areas when there was congruity. This can only mean that these areas that are known for conflict management also play a role in integrating visual and linguistic information. One may wonder if these results were because of the type of participants recruited (immigrant Chinese–English bilinguals in the USA). Would the results have been different if one took Chinese–English bilinguals in Beijing? Bilinguals in these distinct cultural–linguistic landscapes have grown up seeing different kinds of face–language pairings. These data reveal a cultural angle to the issue of the neural basis of language control beyond the fact that faces are linked to languages.

There have been some attempts to explore whether bilinguals, irrespective of their cultural heritage, have better executive control than monolinguals. For example, Yang, Yang, and Lust (2011) studied executive control among Korean–English bilingual children and compared them with monolinguals from the USA and Korea. The bilingual children performed better than all monolinguals, irrespective of culture. Interestingly, the Korean monolinguals were found to have better accuracy but paid the cost in speed compared with monolinguals in the USA. Could there be a culture angle to this difference? The authors argued that bilingualism was a greater predictor of executive control performance, albeit the influence of cultural cannot be entirely ruled out. Further, one cannot say from such data what the effect of
acculturation is on the immigrant children as they grow within an analytic culture and adapt to its style of cognitive processing. Comparative studies of this sort will reveal the effects of the long-term effect of culture on one’s cognitive processing independent of bilingualism.

What happens when someone moves from one culture to another whose cognitive processing styles are different? How do Chinese–English participants who move to western countries (a different culture) learn to adapt to the control mechanisms? An intuitive guess is that the duration of stay in the new culture should correlate with any behavioural or neural evidence and such people should differ from the natives who are still in their own countries. This point is important since many bilinguals now move into cultures other than their own and find themselves with new challenges. Such adaptations are both linguistic as well as cognitive. Pan Liu, Rigoulot, and Pell (2017) studied Chinese immigrants to Canada and North America on the emotional Stroop task and oddball paradigm. The idea was to see whether these immigrants’ behavioural and neural data resembles natives as they spend more time in that culture. The study revealed that such immigrants who have spent a long time in Canada showed similar EEG (electroencephalogram) effects to North Americans. This means that, as a function of social and cultural assimilation, their neural structures started to adapt. Such data could cast alternative interpretations on many studies where immigrant bilinguals have been studied. Most often these bilinguals are young students who have been students in western English-speaking universities for some years. The problem is that unless we know what baseline changes normally may have happened because of adaptation to a different culture we won’t know the additive impact of bilingualism on neural functioning.

In summary, the cultural angle to neuroscience data is pretty important in at least the bilinguals who are mobile and who come from diverse cultures. My intention is not to question the authenticity of the data that we have got so far but to look at it from other perspectives as well since bilingualism is a social and cultural phenomenon. The predictions of the adaptive control hypothesis, for instance, could be expanded to include culture-specific variations. These effects could be at the level of cognitive control and also quantum of switching. Of course, for a general neuroscience-enriched theory of bilingualism and control to emerge would require the inclusion of the diversity issues. Since bilingualism is, after all, a window to the mind (Kroll & Bialystok, 2013), the neurocognitive approach has to consider how culture influences the mind.

5.5 Studying the Cultural Brain and Bilingualism

In this final section, I address some obvious anomalies that have already appeared in the reviews of papers and ideas so far. It is clear that bilinguals and monolinguals may have a fundamentally different neural structure for language control. fMRI studies show that bilingual brains show greater functional connectivity than monolinguals among important brain areas (Grant et al., 2014). A key question then is
whether we can compare bilinguals and monolinguals given the differences in the neural organisation? Parker et al., (2012) examined bilinguals on different linguistic tasks when they performed these tasks only in their first language. Therefore, they had to stop interference from the second language when they used only the first language. When task demands for the monolinguals were increased these same areas were active. This may suggest that neural differences between the bilinguals and the monolinguals are only a matter of control.

In their review of bilingualism, Costa and Sebastian-Galles (2014) discuss the neuroscience research on bilingualism. They point out that so far there are no clear data on the longitudinal development of neural structure from childhood onwards. How does increasing second language proficiency sculpt the brain? Does increasing proficiency lead to increasing demands for exercising control? This is a difficult question since it is not easy to say whether a low or high proficient bilingual faces more difficult challenges or language control. Research has shown that high proficient bilinguals activate both the languages in parallel much more (Mishra & Singh, 2016) and hence it is reasonable to expect that they will need more executive control to sort out the conflict (Singh & Mishra, 2012, 2013, 2015). On the other hand, people with low second-language proficiency also struggle to find the right words to speak in this language. The nature of control in these two cases is clearly different. This difference is central to our understanding of how bilingualism changes the neural structures of the brain over time. Increasing second-language proficiency has been shown to correlate with an increase in grey matter volume (Abutalebi & Green, 2016). The age at which one acquires the second language influences the development of the cortical networks. Neural functional and structural organisation differs for those who have acquired a second language early and who have higher proficiency in it (Liu et al., 2017).

Another important question regarding bilingual language control is whether such control is comprehension or production based? Of course, intuitively it makes sense to assume a model of control that is based on production, which certainly involves difficult language selection. The other issue is whether the activations in the ACC that many have reported during bilingual language control is specific to language or is domain-general. Activations in the L-IFG and DLPFC have been found only during production and not when bilinguals listen to language (Abutalebi & Green, 2016). The ACC has also been shown to activate during language-switching tasks. Blanco-Elorrieta and Pylkkänen (2016) studied Arabic–English bilinguals on language and non-language-switching tasks to see if the neural control is language specific or domain-general. Bilinguals were given stimuli to switch both in production and comprehension. The data showed that DLPFC was active during switching in production as well as during category switching. In contrast, switching during comprehension recruited the ACC. The very high temporal nature of MEG (magnetoencephalography) data showed that neural activity related to switching starts within around 400 ms of stimuli onset. Unless it is assumed that inhibitory control is very crucial in language control, there is no need to assume that the ACC is involved in language control. Behavioural data from high proficient bilinguals on linguistic and non-linguistic switching tasks show that these bilinguals do not use
inhibitory control during language switching whereas the same bilinguals use inhibitory control during non-linguistic task switching (Calabria, Hernández, Branzi, & Costa, 2012). If language production and comprehension are treated as very different processes then there is no need to assume that executive control is involved in comprehension, which is a passive process. Pickering and Garrod (2013) have proposed language production and comprehension to be highly dependent. As per their theory, language production and comprehension form a single action–perception chain. We produce language depending on how we have comprehended language. Data supporting this theory have also come from studies of joint naming (Gambi & Hartsuiker, 2016; Peeters, Runnqvist, Bertrand, & Grainger, 2014). Thus, currently there are divergent views regarding the functional similarity and differences between production and comprehension.

There is also the question of the laboratory-based switching tasks not being particularly sensitive in capturing the actual mechanisms. It is, of course, the case that laboratory-based tasks do not mimic what happens in actual everyday behaviour. It is not known what kinds of control mechanisms bilinguals use when they naturally switch during a conversation. Do they recruit inhibitory control to the same extent they use in a language-switching task in a laboratory? It may well turn out that our theorisations about the domain-general inhibitory mechanisms and their involvement in language and non-language switching are an artefact of the task. Blanco-Elorrieta and Pylkkänen (2016) have shown that there is little activation of the prefrontal control areas and ACC when bilinguals listen to a more natural speech. However, these same bilinguals show activation of executive control-related areas when they do switching tasks in the laboratory. Kleinman and Gollan (2016) have also observed no switch cost during more natural language production. It is unclear if language proficiency or context influences such outcomes. Nevertheless, this is central to our hypothesis concerning domain-general linguistic and non-linguistic control mechanisms in the brain. If bilinguals do not necessarily use a lot of control during natural speech and conversation, then we may have to re-look at the experimental paradigms.

In summary, current evidence suggests that neural structures such as the ACC, DLPFC, and other frontal and parietal areas show some activity when individuals try to sort out conflict or exercise executive control. This happens in both bilinguals and monolinguals. To what extent the practice of bilingualism per se above and beyond other attributes modulates the activity of these structures is an open question. Much evidence suggests that bilingualism is one of the variables that influences executive control, among many others. Valian (2015) did point out that anyone engaged in cognitively demanding tasks for which executive control is necessary may develop these cognitive abilities. If these individuals also happen to be bilingual then this may be additive. Current tasks cannot separate out these individual contributions to task effects since today no one is just bilingual—they also engage in other demanding skills that are add up to one’s cognitive reserve. Further, there are few data on how core cognitive attributes change over one’s lifetime irrespective of bilingualism. For example, major cognitive functions such as working memory and attention start to show decline as people age (Morcom, 2016). This decline
could start as early as at 30 years old. If this is the case, then our claims about bilin-
gualism and its advantages in old age should be re-looked at. If, in general, cogni-
tive functions that are central to language learning, production and comprehension
begin to decline when one is middle-aged or before, then it is not clear how bilin-
gualism can alter this very much since the practice of bilingualism itself requires
many of these functions to be in top order. Of course, one can argue that this very
decline is slow in bilinguals. However, we do not have such large-scale longitudinal
data to infer this at the moment.

5.6 Summary

Neuroimaging data are invaluable in understanding how cognitive structures arise in
the brain through a nature–nurture interface. It is very likely that bilinguals indeed
possess certain specific brain structures or achieve certain functional connectivity
over time that is different to that of monolinguals. Managing two languages over
many years may bring neuroplasticity. However, the very word ‘managing’ requires
further clarification than we currently have. As I indicate, the main controversy in
the field is on the issue of control and how exactly it is implemented by the bilin-
guals. If it turns out that our ideas and theories of control in bilinguals is an artefact
of the experimental paradigms we have used (e.g. in an object naming task or Stroop
task) and we really do not know how fluent bilinguals bring any control at all during
everyday use of language in real life, then it is time to re-evaluate. Further, brain
imaging data being temporally slow does not reflect at what timescale decisions
pertaining to cognitive processes are taken in the brain. Nevertheless, newer studies
with resting-state data and functional connectivity analyses have revealed how bilin-
gualism may sculpt the brain. If indeed the practice and maintenance of bilingual-
ism brings such changes to neural functioning, then this has great therapeutic value.

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Chapter 6
Bilingualism, Context and Control

6.1 Context, Environment and Bilingualism

Most experimental approaches in cognitive psychology and even cognitive neuroscience do not incorporate the context of the phenomena. Bilingual speakers are embedded in a larger context which includes other speakers with diverse backgrounds. In this chapter, I explore the idea that maybe our understanding of bilingualism and its role in cognition is limited because of the methods that have been used. For example, most studies on language production and naming have used a switching task involving colour cues. But that is not how speakers switch between languages in real life. They perceive faces and also think of languages that are linked to the faces and then use the faces to guide language selection. Studies of executive control have used tasks that often do not mimic actual real-life situations. How does one know that inhibition seen in a colour word Stroop task is the sort of mechanism one applies when faced with a socially incongruent situation? For example, when a bilingual speaker is uncertain about the language identity of the interlocutor? One can imagine many other such interactive and social situations that have demands similar to what one may face with non-linguistic tasks such as the Stroop and the Simon tasks.

Currently, there are only a handful of studies that have brought context into the debate. ‘Context’ here could be a face, a visual cue, some picture or even a sound that is linked to the bilingual’s language. How do bilinguals know that they have to select a certain language at a certain point in time during the discourse in a certain situation? Unless they are constantly aware, such selectivity may not be fluent. We do not know how bilinguals maintain such awareness all the time. Of course, in real life there are no coloured cues around us to guide us to select languages. One has to use salient perceptual cues and know that a certain language is suitable for someone. Thus, control then becomes a mechanism related to the perceptual analysis of cues linked to languages. Bilinguals have to know which language is linked to which interlocutor. This tagging of a language with something external is the most
important aspect of a bilingual’s cognitive life. The bilingual brain has an exceptional ability to link different attributes to stimuli (just as objects have two different names in two languages) and later use this indexing to refer to them. Grosjean’s research (2010) on the bilingual mode emphasises context. The bilingual understands environmental cues to set the language mode.

The sections that follow cite and discuss research showing that bilinguals are very sensitive to others. This sensitivity reflects in the control of their own behaviour. Bilinguals attach language cues to faces and even cultural objects from infancy (e.g. Weikum et al., 2007). Bilinguals know that one face is linked to two different languages and when they see that face those two languages are activated. More recently, for example, Blanco-Elorrieta and Pylkkänen (2017) have shown that bilinguals show neural activations as soon they see an interlocutor with regard to language selection. The emphasis is not just to examine switching, shifting and monitoring using psycholinguistic paradigms but to ask more fundamental questions related to bilingual cognition. Why are bilinguals sensitive to visual cues and how do they influence their language mechanism? Understanding the nature of executive control in bilinguals now has entered into the domain of social cognition (Bialystok, 2015). While the replication debates have been around task and statistics, one important point has been missed—that is, the contextual explanation of bilingual cognition. If bilinguals and monolinguals perceptually process stimuli differently, then this may explain the way they differ on other complex cognitive functions.

6.2 Adaptive Bilinguals

Cognitive agents adapt to the changing demands of the environment. Adaptation may include modifying and controlling behaviour that is appropriate for that occasion. Bilinguals need to interact with both bilinguals and monolinguals in a given context. Since a speech community may comprise diverse types of speakers, the bilinguals need to adapt to the interlocutors quickly. When Green proposed his inhibitory control model (Green, 1998) he had a single bilingual speaker in mind. The nature of inhibition in a solitary situation (e.g. while performing an object naming task) can be explained looking at just the task demands. However, this modulation was not because of some external agent or an interlocutor. More recently, theorists have been including the context of interlocutors and other agents in the environment which influence how the bilingual controls his or her language. A bilingual’s ability to adapt his linguistic behaviour is a result of the cognizance of the interlocutor. Green and Abutalebi (2013) have recently looked into the ecology of the bilingual speakers and how we may consider factors that influence cognitive control.

Green (2011) focuses on the varieties of speech communities and their switching behaviour. If a community does not encourage language switching often then the bilinguals within that community may not switch often. This is what Green calls the ecology of the bilinguals as a function of a switching or non-switching community (Green, 2011). I do not think we yet have good-quality data on bilingual speech
communities around the world and their switching behaviour. Nonetheless, theoretically linking the percentage of switching (or opportunity to switch) to exercise of control makes logical sense. Green proposes a single-language and dual-language context. These contexts are defined in terms of language-switching practices in a community. In some speech communities, bilingual speakers often switch between two languages, and in others they restrict to one language. Green thinks that bilinguals who are of the dual-language type may recruit more executive control for monitoring than those who are in the single-language type. The frontal and cerebral regions that mediate control will be highly exercised in the bilinguals who are of the dual-language type. Green’s classification makes empirical predictions with regard to what we may see on non-linguistic executive control tasks if such bilinguals are compared. Depending on the language context (dual or single), bilinguals modulate their cognitive control. Green writes that “if functional demand shapes neural circuits then there may be structural correlates in the regions linked to control. In communities where speakers must switch on demand between their two languages, anterior cingulate and/or left inferior frontal regions may show greater gray matter density compared to monolingual speakers of just one of those languages. In contrast, in communities where bilinguals code-switch, right cerebellar structures may show enhanced gray matter density.”

How does one examine this in an experimental context? If the experiment involves object naming, then single- or dual-language contexts can be induced. In a single-language context, there is no demand for switching. In the dual-language context, the speaker knows that he may have to switch. The object name is selected early in a single-language context. In the dual-language context, the selection is late as there is both switching and inhibition. The caudate nucleus shows selective activity in this contextual difference. Grosjean (2001) has also suggested that bilinguals in dual- or single-language contexts are basically operating in two different modes. Executive control may not be exercised in those bilinguals who do not switch a lot.

Hartanto and Yang (2016) compared dual- and single-language bilinguals on typical switching tasks. The bilinguals were a Chinese–English-speaking population from Hong Kong. They were divided into these groups based on their demographic histories and also language use background. The authors found smaller switch costs for the dual language-context bilinguals compared to the single language-context bilinguals. The results showed that, depending on the bilingual environment and its everyday demands, executive control requirements are modified. However, there are many factors that can influence how one uses language in general.

6.3 Faces, Scenes and Interference

Green and Abutalebi (2013) proposed that bilinguals are sensitive to visual cues in the environment. Visual cues can be faces or cultural objects linked to languages. Although face perception has been shown to be one of our fundamental and
automatic cognitive abilities (including the suggestion that there might be a face-processing area in the brain), it is only recently that bilingual language processing has been shown to be influenced when bilinguals are exposed to faces. If faces can influence bilingual language processing, then this may provide strong evidence for adaption. Li, Yang, Scherf, and Li (2013) examined how Chinese–English bilinguals are sensitive towards Chinese or non-Chinese faces during language production. Chinese–English bilinguals were faster naming an object in Chinese in the presence of a Chinese face. Similar facilitation was also seen when they named objects in English alongside a Caucasian face. This suggests that faces primed corresponding languages. In other words, we can say that the bilingual speakers activated the language that they thought was suitable for the particular interlocutor. However, there was no interference where the face was incongruent with the language to be used.

Not just faces but images linked to culture similarly influence bilingual language activation. Zhang, Morris, Cheng, and Yap (2013) presented scenes that belonged to Chinese culture to Chinese–English bilinguals and found that this interferes with their English production. This inhibition arises from activation of Chinese from the images. Roychoudhuri, Prasad, and Mishra (2016) examined this issue in the Indian context. They argued that not just faces but images linked to culture similarly influence bilingual language activation. The bilinguals studied in both Zhang et al. (2013) and Li et al. (2013) were not proficient in English. Further, the linguistic climate in the USA where the study was carried out was English. In such a situation, these bilinguals may not often switch between Chinese and English in everyday communication.

The participants in the Roychoudhuri et al. (2016) study were Bengali–English university students. Unlike the studies on Chinese–English bilinguals in the USA who were immigrants away from their home culture, these students lived in the same country but in a different province. Participants were students at the University of Hyderabad (a metropolitan multilingual city in India). The lingua franca of the university is English and all teaching and research are conducted in English. In this overwhelmingly English-dominant climate, it is natural that these bilinguals will have less opportunity to use Bengali often. However, Bengali is used in non-work-related scenarios by these groups as well as Hindi, which is the official language of India. A sample trial from the study is shown in Fig. 6.1.

In this study by Roychoudhuri et al. (2016) iconic culture images appeared in the background. The images were selected after ratings by Bengali–English bilinguals to ensure that these images represented Bengali culture. Speakers were slow in English naming when the background image was a Bengali culture image compared with a neutral image. There was also statistically non-significant facilitation during Bengali naming when the image was culturally congruent compared with neutral images. The patterns of results suggest that even though the bilinguals had been living and studying in another province, they are sensitive to their native culture image and this sensitivity penetrates into language planning. However, these results did not fully replicate the earlier observations with Chinese–English bilinguals. It is important to note that while Zhang et al. (2013) had observed interference in second
language (L2) naming with culture images, Li et al. did not report any interference. Rather, their results showed facilitation when the face was congruent with the language to be used for naming. The discrepancy between these studies is fascinating since both studies have used immigrant Chinese–English bilinguals who have been living in the USA.

Faces are more immediately perceived because of their evolutionary significance, while images may take time to have the same effect. Further, while faces and their cultural ethnicity are perceived immediately, speakers may differ on how they relate any image to their culture. When one sees a face, a conversational mode may set in more quickly as opposed to seeing a natural scene. Further, the contrast between a Chinese face and a Caucasian face is strong and direct for the perceptual system, thus offering a good comparison for analysis. Whereas the so-called iconic images of a culture and neutral scenes used in some studies may share bottom-up similarity. Questions have been raised regarding the participants’ proficiency in English as this may explain their being slower in naming in English. Chinese–English bilinguals and Bengali–English bilinguals may differ a lot with regard to their English competence. As reported in these studies, the Chinese–English bilinguals acquired English much later in life whereas Indians are taught English very early because the educational system emphasises English throughout. Irrespective of these differences, it is clear that faces and images evoke language and bilingual brains can track this. This is not merely a perceptual issue but has a cognitive effect on language production.

**Fig. 6.1** Experimental procedure from Roychoudhuri et al. (2016). Each trial started with an image representing Bengali culture (Goddess Durga or Howrah Bridge). Neutral images (single coloured textures) were presented in some trials as a baseline. The colour of the central box indicated the language to be used to name the subsequent object. In this example, the image of Howrah Bridge acts as the culture cue and the red square cued speakers to use Bengali to name ‘banana’.
Visual cues in the environment point at the appropriate language in a given context. These cues are tagged to specific languages such as a face or cultural picture. Different cultures and the level of bilingualism practised within them may influence such sensitivity. One key question is whether all bilinguals are equally sensitive to such cues? Does executive control play any role in this interface between the perceptual system and language activation? The studies discussed so far did not correlate their effects with the executive control of participants. Hartsuiker (2015) suggests that the issue of cultural cues and language activation cannot be sorted out without understanding how visual cues really influence lexical activation. Culturally or ethnically, congruent images may prime particular language, but observing inhibition in incongruent situations is difficult to explain. Inhibition probably results when spontaneous activation of a language from an image is incongruent with the response. Without many other studies taking into account the bilingual ecology of speakers, we cannot theorise on this causal relationship.

It is possible that if in a given cultural context, bilinguals are exposed to a diverse range of interlocutors who speak different languages, they may be more alert as opposed to more homogeneous cultures. For example, different types of bilinguals in India may be part of the same language landscape, whereas in the USA the environment is largely English speaking. Further, these bilinguals may have different levels of proficiency in the two languages. Switching is an outcome of the possibility of practicing different types of bilingualism with different interlocutors in a given environment. Looking at a bilingual interlocutor thus means to assess both the languages and select one that is to be used for speaking during communication.

Another related and important question is how do bilinguals resist the influence of faces and culture images? Such cues can distract them from their own language-selection goals. Imagine a bilingual who is in a monolingual mode (in the sense of Grosjean) and has selected to use only one language with the interlocutor. This calls for inhibition of the other language constantly and deliberately. The environment may have faces or images that are linked to the language, which the bilingual is trying to inhibit. I would like to speculate that the degree of sensitivity and the requirement of executive control for such a situation will differ vastly between cultural settings. Different bilingual settings prevailing in different countries will directly impact how bilinguals manage this interference. It is not clear how faces and culture images may induce switching in the bilingual during a natural conversation. Therefore, going beyond bottom-up priming (which explains why any face or image provokes a language), we should look into the environment and particular types of bilingualism and their interaction.

### 6.4 Presence of Interlocutors

Executive control that bilingual brains exercise is linked to interlocutors. Bilinguals decide which language to pick based on the interlocutors. Just as faces and natural scenes prime the languages linked to them, similarly bilinguals select languages
appropriate for an interlocutor. While cueing studies have examined language selection under instruction, few have explored how the mere presence of an interlocutor can lead to language selection. The communicative and contextual forces that modulate bilingual language selection is a new paradigm in research (Green & Abutalebi, 2013). Bilinguals may find themselves in a context where there may be multiple interlocutors around. Thus, language selection will depend on whom they intend to address. Language switching between different interlocutors requires higher control.

Grosjean (2001) suggests that the emergence of language mode is dependent on the language proficiency and dominance of the speakers. Green and Abutalebi’s (2013) adaptive control hypothesis suggests that various language contexts (single, dual) bring in different switching patterns. Figure 6.2 demonstrates situations involving language selection in bilinguals when they are interacting with other bilinguals/monolinguals where native language (L1) is Hindi and L2 is English. So far no theory accounts for how the bilingual brain considers and resolves such complex interactive contexts. For example, when a bilingual interacts with a monolingual and some bilinguals with low proficiency in L2, he might maintain a high level of activation of L1 and hence prefer to use L1 in such a scenario (Situation C). In

![Fig. 6.2 Three possible interactive situations for a bilingual. When a bilingual encounters other bilinguals with balanced proficiency in both the languages, he has to actively maintain both the languages and shift between them (Situation a). But, when a bilingual encounters monolinguals, activation of L2 has to be completely inhibited and communicate only in L1 (Situation b). A more complex situation arises when a bilingual encounters a mixed set of interlocutors. In such a case, the bilingual has to carefully monitor the context and choose the appropriate language. In the situation depicted here (Situation c), a bilingual is in communication with monolinguals and other bilinguals who are low proficient in L2. Here, the bilingual would be expected to maintain a high level of activation of L1 as it will facilitate communication with all his interlocutors.](image)

6.4 Presence of Interlocutors
contrast, if a bilingual encounters only monolinguals, he has to completely inhibit L1 (Situation B). Therefore, the emergence of a mode is entirely dependent on the situation and the assessment of the mutual language proficiencies. I have remarked that the interactive context of bilinguals is culture-bound. In any communicative setting in India, one has to be prepared to interact with a diverse set of bilinguals and monolinguals. Thus, it is not possible to just maintain a particular language in any given situation. This is probably not the case for the bilinguals in the USA where L2 communication generally happens in specific contexts. To conclude, language selection, the quantum of switching and the degree of maintenance of activation level of a language are entirely dependent on the quick evaluation of interactive contexts. Further research is required to study cross-linguistic interactional contexts rather than struggle cross-sectionally. My own study, which is discussed later (Kapiley & Mishra, in press), looks at bilingual language control as a function of the assessment of interlocutor language proficiency, beyond merely tagging a language to a particular face.

The first important point to note is the sensitivity of bilinguals to interlocutors. This sensitivity manifests in the form of their awareness of the interlocutors’ language and cultural background as well as knowledge about their preferred languages during communication. Bilingual speakers know whether the interlocutor is bilingual with good proficiency in both the languages or a monolingual. Language management during live communication is contingent on this mutual knowledge. The bilingual may deactivate one language when talking to a monolingual interlocutor and keep both languages active when the interlocutor is a bilingual (Grosjean, 2001). If the interlocutor is less competent in one language, then the bilingual may select the language which suits the interlocutor in a greater number of instances. This point probably lies at the heart of the adaptive nature of bilingual language management since this affects the switching possibility during an interaction. More traditionally, interlocutors have been understood as those who directly interact with the speakers. What if the interlocutors are not actively engaged in communicating but are passive in the scene?

Bhatia, Prasad, Sake and Mishra (2017) addressed this issue using a voluntary naming paradigm. Voluntary naming for a bilingual speaker induces language choices in each trial. In this paradigm, speakers choose a language to name an object freely. Voluntary naming may induce decision-making demands and speakers often select their dominant language for naming (Gollan & Ferreira, 2009; Gollan, Kleinman, & Wierenga, 2014). Bhatia et al. (2017) explored whether the presence of a cartoon (depicted as an interlocutor) influences the voluntary language choice of Hindi–English bilingual speakers. At the beginning of each trial, a cartoon character appeared waving at one of the two colour patches on the screen. Each colour patch was related to the response keys that the speakers needed to select to indicate their language choice for the voluntary naming task. The authors were inspired by a study where Dolk Hommel, Prinz, and Liepelt (2013) showed that even a Chinese cat that sat on a table and randomly waved its hands influenced participants’ performance on a Simon task. Similarly, are bilinguals sensitive to the presence of other speakers in their environment who may influence their language choices? If so, then
one can suggest that bilingual language activation can happen by mere exposure to stimuli present in their environment. Bhatia et al. (2017) found that speakers often chose the language indicated by the cartoon character through waving at the colour patches. Importantly, the cartoon character did not speak or select a language explicitly—the cartoon was not a partner in any communication with the speakers. This study demonstrated that bilingual speakers are sensitive to visual cues in the environment that are linked to relevant languages; it influences their own decision-making regarding language use.

One can say that this is easily explained by a bottom-up processing mechanism where the colour patches primed language selection. However, this does not demonstrate that the cartoon character’s waving influenced how speakers decided on the language to use. In the experiment, the speakers first selected the language and then saw the objects. It is possible that the colours just primed and biased the speakers’ selection. However, language selection for the speaker was a top-down intentional action. If such an action was influenced by the cartoon character’s actions, then we have to accept that even language selection is affected by other agents’ actions, but these actions are not necessarily related to speaker’s own actions. The data suggest that if language choice is considered an action and language selection is a decision-making act, then this is vulnerable to other agents’ actions.

The Ideomotor theory of action control (see Hommel, 2013 for a review) proposes that any action and its outcome are linked representationally in the mind. We acquire this relationship during development. Action outcomes provoke sensorimotor preparation ahead of the actions. In this way, others’ actions start influencing our own action. We embody their sensorimotor action link. Studies on joint tasks show how agents incorporate one another’s action choices when they do the same task together. Recent developments in the socio-motor action control framework suggest that we learn our action outcomes through their effects on other agents (Kunde, Weller, & Pfister, 2017). Thus, when they perform the same actions, we also mimic them unintentionally. This is very relevant in understanding bilingual language activation and language control in a social setting. This is so because we are interested in a theory that offers a holistic explanation of how exactly language selection and control works in bilinguals.

Suppose two bilingual speakers are taking turns to try and name an object. They will activate both names of that object in parallel. The task is a joint task and each person takes a turn in selecting a language and naming the object. Suppose the bilingual speaker ‘A’ sees speaker ‘B’ select L1 to name the object. Will this, in turn, lead to higher activation of L1 in speaker ‘A’ when he tries to select the language when his turn comes? If this happens, then we can say that speakers’ own language selection is contingent on what they think others are doing in the social context. This alignment has also been studied in the pragmatics of turn-taking and sentence priming (Pickering & Garrod, 2004). In the example I gave, both the speakers are not communicating with one another and have no speaker–hearer relationship. Yet they are co-agents in a task and one’s language selection depends on the other. This simple task has the potential to reveal how bilinguals are sensitive to fellow bilinguals’ language selection. Gambi and Hartsuiker (2016) recently showed the same
with an elegant experiment. Two bilingual speakers were asked to name objects in turn. One of the participants voluntarily selected the language, whereas the other participant always spoke in one language (L1). Surprisingly, the responses of the non-switching participant in L1 were slowed down if the partner had spoken in L2 on the previous trial. The results showed that one bilingual’s language selection influenced the language activation in the other. Thus, social influence on language selection can be both top-down and bottom-up.

The study by Bhatia et al. (2017) also raises other questions related to self-action versus actions provoked by other agents. Since the participants selected their own language, we assume that they were exercising their free will. When an external agent’s actions provoked them to choose one language over the other we can say that such a mechanism was also under bottom-up control, although participants presumably do not have an explicit idea that the cartoon is influencing their action. Importantly, the cartoon influenced voluntary language switching. Language switching in bilinguals could be both under top-down and bottom-up influence. The cartoon character’s actions biased the activation of a certain language towards one of the responses and then speakers selected it with greater probability. External influences modulate the internal natural switching behaviour and also the preferred choices of the speaker with regard to the dominant language. However, the study did not show any effect of the cartoon character’s behaviour on naming latency, which was unaffected by this influence. It is possible that influences on language schema selection in a bilingual may not always affect the latency. While bilinguals may choose a language because of this influence, how this reflects on the naming latency cannot be predicted.

Bilinguals keep track of interlocutors and their languages across time and pace. This means that they remember which languages are to be tagged to a particular interlocutor. This indexing of languages to a face facilitates lexical access when needed. Woumans et al. (2015) asked people to indulge in simulated Skype interviews for some time. During this interaction, presumably, participants learnt to associate languages that their interlocutors spoke. Later in the main experiment, they were asked to produce a word associated with the word produced by the interlocutor. Speakers were faster responding to faces that used the same language as in the Skype session. This means that the participants kept the mental representation of the interlocutors, tagging particular languages with them. When there was a match, they were faster. However, they became slower when the language did not match with the identity of the speaker as introduced. Further, when the participants became aware through the course of the experiment that the interlocutors were indeed bilinguals and not monolinguals, this effect disappeared. This data suggests that bilingual speakers create mental models of language preference and use with particular interlocutors. This mental model guides them in language selection and switching.

Are all kinds of bilinguals capable of exploiting an interlocutor’s identity to select a language? It may be that only early and high proficient bilinguals are more sensitive to visual information and language identities. Molnar, Ibáñez-Molina, and Carreiras (2015) introduced participants to several interlocutors who spoke different languages. Later, an audio-visual lexical access task was administered. Participants
were faster when the language matched with the interlocutor’s language. However, this effect was found only in early bilinguals. Martin Molnar, and Carreiras (2016) further tested if early bilinguals are able to use interlocutors as cues to predict language. The authors exploited the fact that one can predict the language of a monolingual speaker but not of a bilingual speaker. A bilingual can use any one of the languages at his disposal whereas a monolingual is associated with only one language. The authors recorded EEGs (electroencephalograms) as the interlocutors were shown on the screen. The interlocutors produced language that the participants had to respond to. Importantly, EEG effects show that much before the interlocutor spoke, participants could use their faces as cues to predict the language associated with them. For the monolingual, they could predict ahead which language he is going to speak, but for the bilingual this was not possible. The central claim of the paper was that bilinguals use interlocutor identity to predict languages associated with them. However, how stable is this interlocutor’s identity?

This effect is predicted when one thinks of the interlocutors as balanced bilinguals who can use any one of the languages any time. However, bilinguals differ in their language proficiency—they are never perfect in both languages. In this case, then most interlocutors would be associated with one language predominately. This language could be the one perceived as having greater proficiency or fluency. This is how most second-language learners behave with regard to their proficiency. For example, in a country like India, most students acquire English as a second language at school and develop proficiency in this language differently. Not all who claim that they are bilinguals with English as a second language are proficient in English. Many studies of such bilinguals by Mishra and colleagues have shown this proficiency difference, which in turn has been linked to their executive control (Singh & Mishra, 2012, 2013, 2016). Thus, it is possible that in a communicative situation one may encounter bilinguals who are good in one language but not in the other language. Suppose one interlocutor is introduced who is proficient in English but the other is not that perfect and mostly uses, for example, Hindi (India’s national language). These bilinguals can be classified as low or high proficient in the second language use. However, their first-language abilities are similar. Kapiley and Mishra (in press) have explored this situation with Telugu–English bilinguals in India and found that bilingual speakers are sensitive to the language proficiency of their interlocutors. Figure 6.3 shows a sample trial and results from this experiment.

In this study, Telugu–English high proficient bilinguals were introduced to cartoon interlocutors through a simulation. The participants were presented with speech samples of cartoons in both Telugu and English. The participants implicitly learned that the cartoons differed in their L2 proficiency. Later, they were asked to perform a voluntary naming task. Before the participants selected the language to name the object in, the cartoons were presented randomly on the screen. The assumption was that as soon as the cartoons appear the participants will attach a particular language to them (the language they are fluent in) and this activation may influence their choice of language. Crucially, unlike the studies by Molnar et al. (2015) and Woumans et al. (2015), here the authors sought to know whether the
speakers take into consideration the language proficiency of their interlocutors. If speakers want to adapt to and accommodate their interlocutors then they must evaluate their language proficiency and they should activate the language the interlocutor is good at. Of course, one can argue that in this particular case the speakers are associating both languages with interlocutors portrayed as low and high proficient since they all are bilinguals. However, it is claimed that speakers will mostly tag a particular language with an interlocutor (s/he is good in this vs. that) and this knowledge will influence how they select their own language. Although in the experimental design the speakers did not directly interact with the interlocutors, their influence was seen in voluntary naming.

The results showed that when speakers were presented with interlocutors who were perceived as highly fluent in English (L2) they often chose English as their language of choice for naming. When the interlocutors were perceived as low proficient in English they chose Telugu instead. These results thus demonstrate that speakers don’t just tag a certain language with an interlocutor, but they seem to have critical knowledge of their language proficiency. This is particularly relevant for bilingual contexts in which there are no monolinguals. In such a scenario the
contrast is not between bilinguals and monolinguals but between types of bilinguals. The variable that distinguishes them is their relative proficiency in the second language (typical in Indian university students). These results also show that interlocutors’ influence can penetrate into the planning of one’s own voluntary actions. This had not been tested before in studies that examined whether bilinguals are able to associate a particular language with particular interlocutors. This association is not just symbolic, it also affects language planning. With regard to the issue of executive control as per the adaptive control hypothesis, it can be said that knowledge of interlocutors’ language proficiency can help modulate control. Although Kapiley and Mishra (in press) did not correlate the speaker’s adaption with their own executive control, it is possible to speculate something along these lines.

More recently, using MEG (magnetoencephalography) it has been shown that the interlocutor’s identity is considered pretty early on during bilingual language planning. Blanco-Elorrieta and Pylkkänen (2017) examined Arabic–English bilingual speakers to examine how early during language planning the interlocutor identity starts playing a role. Participants had to perform both a production and a comprehension task. A sample image of the main experimental conditions is shown in Fig. 6.4.

Participants saw the interlocutors and then were asked to name a picture as quickly as possible. Similarly, for the comprehension task they were asked to judge whether the spoken word was a meaningful word. The idea was to see whether seeing a bilingual interlocutor as opposed to a monolingual interlocutor has any effect on both behavioural and neural aspects of switching. The assumption was that
speakers will activate both languages on seeing a bilingual participant and therefore the switch cost may go down as opposed to seeing a monolingual interlocutor. Neural activations from MEG recording showed that when speakers saw bilinguals as interlocutors they prepared to switch earlier and this led to the behavioural costs. Although these results have been observed in different paradigms, they indicate a few things in common. First of all, bilinguals take advantage of their interlocutors’ identity when planning speech. This identity may be only with regard to whether they are monolinguals or bilinguals or if they are high or low proficient bilinguals. Thus, social cues related to interlocutors affect the recruitment of executive control. One can see this effect on a non-linguistic task or on switch rate. Bilingual interlocutors can provoke the speaker to prepare both languages, and if they are monolinguals then speakers can just select one language.

Apart from influencing language planning, how does interlocutor awareness influence cognitive functioning? Imagine a bilingual speaker confronting either a bilingual or a monolingual interlocutor. He has to keep both languages active for the bilingual interlocutor while he also has to inhibit a language constantly for the monolingual interlocutor. I elaborate on this issue in Sect. 6.5.

6.5 Interlocutors and Control

Does the amount of executive control required during a conversation depend on the interlocutor? So far the studies that have been discussed show that bilinguals are sensitive to the faces and other features of bilingual or monolingual interlocutors. However, the key question is whether interlocutors and such awareness directly influence executive control of bilinguals. The adaptive control hypothesis classified bilinguals into different types who differed with regard to the quantum of switching (Green & Abutalebi, 2013). If interlocutors are responsible for switching then interlocutor awareness should directly affect the magnitude of executive control that speakers may need. Although no substantial data have shown that executive control is modulated by interlocutors, there is a trend in research now. The basic idea is to explore the dynamic adjustments in control as a function of interlocutor awareness.

Let us consider a bilingual who is communicating with a similar bilingual (with good proficiency in both the languages). In another scenario, the bilingual is interacting with an interlocutor who does not have good proficiency in one of the languages. Bilinguals who are similar to one another (in proficiency) can flexibly switch often as both are confident of shifting into any language at will. If one of the bilinguals is not good in a certain language then switching may suffer. Therefore, the requirement of executive control should be much higher when bilinguals with different levels of proficiency are interacting as opposed to when they are similar. This has not yet been directly shown in any experiment. Similarly, when a bilingual encounters a monolingual, the need for control is higher than when he encounters another bilingual. When a bilingual encounters someone about whom he has no
idea, control will develop depending on later assessment of proficiency. Therefore, control is dependent on the dynamic assessment of proficiency of the interlocutor and at times prior knowledge may help.

Costa, Hernández, and Sebastián-Gallés (2008) had shown that the demands of monitoring are increased with increased uncertainty of a situation. They tested bilinguals on a Flanker task and manipulated different monitoring conditions. Bilinguals showed less Flanker cost when the monitoring demands were higher. This can be translated to a conversational situation that bilinguals may encounter from time to time. If the interlocutor is unpredictable or his proficiency does not align with the speaker then the requirement of executive control will be much higher. One can say that the executive control demands can be much higher when a bilingual encounters another bilingual of similar proficiency, assuming both are balanced. In this case, both the speaker and interlocutors are capable of switching language at any time since they have full control over both the languages. Therefore, both have to bring in higher monitoring in order to carry on the conversation. When the bilingual encounters a monolingual or a low proficient bilingual, he has to apply inhibition to one language and keep the other language activated. If this analysis is correct then it will be reasonable to say that the type of control that a bilingual needs is qualitatively different from situation to situation. In one case, he may need higher monitoring and the ability to switch rapidly, whereas in another situation he may need constant inhibition.

When Valian (2015) reviewed the bilingual advantage literature, her aim was not just to highlight the null results and all these studies that had found an advantage. She suggested that we need to better understand exactly what happens when bilinguals engage in the real practice of bilingualism with real interlocutors and embedded within real contexts. It is very likely that we have administered many tasks without knowing if those tasks appropriately capture the kind of control those bilinguals exercised most of the time. When participants are taken into a study at any point in time without the experimenter knowing what type of control the bilinguals have been exercising until that point, the tasks may not capture the underlying mechanism. This may also explain why the results vary when bilinguals from different cultures are compared on similar tasks. However, this type of comparison also has not happened a lot in the literature. Nevertheless, going beyond the proposals of the adaptive control hypothesis, it is time to look carefully into the actual bilingual context of language use via their interlocutors and then determine tests that have the potential to capture any difference. Random administration of tests and their failures may not reveal much about the phenomena under investigation.

Mishra and colleagues (Bhandari, Ramgir, Prasad, & Mishra, personal communication) have been interested in exploring how interlocutors modulate the executive control requirements in a direct manner. One possibility is to see whether bilinguals modulate their executive control differently for different types of interlocutors and this then reflects on some non-linguistic executive control tasks. Bhandari et al. examined this in a novel paradigm with interlocutors and the Attentional Network Test (ANT). Bilinguals were introduced to interlocutors who were high or low proficient in the second language (Fig. 6.5) and the ANT was
administered in the presence of these interlocutors. Bhandari et al. proposed that for
a bilingual, the most demanding interactive context could be when he has to face
both low and high proficient interlocutors together. The speaker has to constantly
monitor language use and switching to both types of interlocutors. When interlocu-
tors are of similar types then monitoring demands may be low.

The participants performed the ANT task in the presence of interlocutors that
either appeared randomly (mixed block) or in single blocks (pure block). These
interlocutors could be high proficient in L2, low proficient in L2 or of unknown
language proficiency (neutral). Further, the participants themselves were divided
into low and high L2 proficient. It was predicted that the high proficient participants
would bring in greater executive control when the context became demanding with
mixed interlocutors as opposed to when they performed the ANT task with inter-
locutors of the same type. The results showed that this was indeed the case. There
was a proficiency effect on the ANT task performance mediated by interlocutors.
Such results show that bilinguals do not just select a particular language for a certain
interlocutor but they modulate their executive control depending on what types of
interlocutors there are in the environment. The adaptive control hypothesis of course
does not include these predictions as of yet, but its main suggestions implicate this.

Fig. 6.5  (a) Different phases in the experiment: participants were first exposed to and familiarised
with the cartoons. The main ANT experiment was administered following the familiarisation
phase. (b) Experimental procedure: an interlocutor was presented first followed by the ANT task.
Interlocutors (bilingual, monolingual or neutral) were presented in a pure (blocked) context or a
mixed context. (c) Results from the executive network: HP bilinguals were faster than LP bilinguals
only in the mixed context but not in the pure context. ANT Attentional Network Test, HP high
proficient, LP low proficient
We used an ANT task to capture these fluctuations in executive control but one can also examine this using other tasks. Task demands and their effects on bilingual control have also been shown by others (Qu, Low, Zhang, Li, & Zelazo, 2016). Of course, based on these results, it is very difficult to say which particular component of executive control bilinguals bring in when they face interlocutors of varied language proficiency.

6.6 The Advantage Debate and the Interactive Model

The bilingual advantage debate at this point in time remains at a crossroad. While some have passed judgment that it does not exist (e.g. Antón et al., 2014; Paap & Greenberg, 2013), others have extended the domains of inquiry (Bialystok, 2017). There are of course others who have alleged publication bias (Paap, Johnson, & Sawi, 2016). Although there have been several conceptual replications, there have been very few direct replications. Importantly this debate has not considered how executive control, if at all, is modulated by the interactive context between bilingual speakers and hearers.

The central claims of the adaptive control hypothesis (Green & Abutalebi, 2013), and also suggestions in the writing of Grosjean on bilingual language mode, link adaptive behaviour with control. The essence of control lies in our appreciation of the fact that the bilingual speaker brings this adaptive behaviour to communicate successfully with various interlocutors. I have suggested (Mishra, 2015 that constant switching in the language domain, which bilinguals do, is not something that monolinguals do. Monolinguals do not need to adjust to bilinguals during conversations. They have only one language at their disposal and if the interlocutor does not know this language then communication stops. It is the bilingual who has to inhibit the language that the monolingual does not know, and therefore this may lead to exercising of the executive control system. The same mechanism applies to when a high proficient bilingual encounters a low proficient bilingual. Mishra and colleagues have observed executive control advantage as a result of second-language proficiency in Indian bilinguals (Singh & Mishra, 2012, 2013, 2016). A recent replication, however, of the study by Mishra, Hilchey, Singh, and Klein (2012) with French–English speaking bilinguals in Moncton, New Brunswick, Canada has not found any correlation between executive control and second-language proficiency (Saint-Aubin et al., in press).

The precise component of executive control that is required in a specific encounter is open to debate. For example, the type of control that an Indian bilingual needs with another Indian bilingual (assuming their proficiency in the second language differs) is different than a Chinese–English bilingual needs in the USA. This point has serious consequences for our interpretations of the data and has escaped many authors’ attention. Further, when the context is multilingual with diverse types of interlocutors present and various language switching habits and proficiencies, the speaker may need greater monitoring. He may have to switch to a different language
randomly with the changes in interlocutors in the communicative context. When the speaker is sure of meeting and encountering only certain types of interlocutors (bilingual speakers in a predominately monolingual country), the control settings are appropriately fixed. This is what has been termed the ecology of the bilinguals (Green, 2011). The exercise of control is directly proportional to the demands imposed by the interlocutors. I think the adaptive control hypothesis should include this and extend the model, going beyond consideration of the switching style.

The naysayers in the advantage debate do not focus on these possibilities. They do not say that maybe the replications did not take place since these factors were not considered. Once they find results do not match, they are satisfied with rejecting the theory altogether. In Chap. 4, I demonstrated why the null results should also be looked at with suspicion since many do not consider critical variables such as participants’ bilingualism style, what kind of executive control they may have acquired given their unique background, and so on. The relevance of these studies expands our considerations into variables that have so far escaped attention. Mere cross-sectional comparative studies without knowing how those bilinguals have achieved their control, if any, in the first place won’t lead to much understanding. Recent studies have shown that bilinguals have better selective attention (Chung-Fat-Yim, Sorge, & Bialystok, 2017; Grundy, Chung-Fat-Yim, Friesen, Mak, & Bialystok, 2017) or a better ability to disengage attention (Mishra et al., 2012). These abilities are necessary in interactive contexts. When multiple interlocutors are present, one has to engage and disengage attention quickly. This mechanism is also linked to language selection.

6.7 Summary

This chapter demonstrates how linguistic and non-linguistic context influences language control and selection in varieties of bilinguals. I would like to note that while Green and Abutalebi’s (2013) proposal justifiably links language control to switching habits of different bilinguals, it is time to expand the range of the hypothesis. Since context is culture dependent, there cannot be one single theory that accommodates diversities. I emphasise the role of language proficiency (particularly in L2) in the Indian context, which might not be the same for western bilinguals. Cross-cultural and cross-linguistic studies using both behavioural and neuroimaging methods can offer new clues about bilingual language control in different contexts. Since language switching and language selection are related in bilinguals, examining contextual influences should help us understand this relationship better. The experimental research that has been discussed in this chapter establish clearly that bilinguals are very sensitive to interlocutors and to other cues which they use for language control. Future research should explore how bilinguals adapt to changing demands in the communicative context.
References


Chapter 7
Attention, Vision and Control in Bilinguals

7.1 The Shades of Attention

In my previous book titled Attention in Human Language Processing: A Cognitive Science Perspective there was a full chapter on attention. That chapter dealt with the various aspects of attention and the tasks people use to measure it. Attention remains the most central and critical psychological concept that explains most of the complex cognitive mechanisms. For useful full-length reviews on attention, the reader may consult other resources (e.g. Carrasco, 2011). Not all shades and types of attention are necessary to understand how bilingual language control uses them. Thus, I restrict my discussion to selective attention and also to disengagement of attention. More recently, executive attention has emerged as a key notion in understanding bilingual language control (Bialystok, 2017). Attention could also explain the inhibitory control as a component of executive functioning (Miyake et al., 2000). Today the key question is not if bilinguals apply inhibitory control for their language selection but whether they have a superior attention that allows them an advantage on a range of tasks.

Attention selects the stimuli that are most important for the current goals and filters out others. At the same time, spatial attention also allows us to orient in space to explore newer objects and locations (Posner, 1980). Attentional focus and its modulation enhance perception and objective knowledge (e.g. Carrasco, Ling, & Read, 2004). The temporal and spatial properties of attention can be very helpful to understand a number of complex cognitive functions (Klein, 2000). Michael Posner first demonstrated the mechanisms of movement of attention and its various components using the cueing task (Posner, 1980). Attention orients in space and time and the effect of this orienting is seen on responses. In the classic cueing task, attention is exogenously captured by brief stimuli, or it can also be endogenously employed at selected locations. When a target appears at such locations, its identification and discrimination are speeded up compared with other locations. However, when a target appears after a delay (e.g. 300 ms), this processing advantage turns into a
cost. This has been termed as inhibitory of return (IOR). Klein (2000) suggested that the nature of attention is to forage around in order to bring in newer objects to our consciousness. Even William James considered that attention to things enhances their conscious perception (James, 1890). In the contemporary discussions on consciousness, many theorists use attention as a key mechanism to explain consciousness (e.g. Cohen, Cavanagh, Chun, & Nakayama, 2012). Further, attention operates like a searchlight whose aperture can be broadened and narrowed depending on top-down goals (Theeuwes, 2010).

Central to Posner’s analysis is the mechanism of engagement and disengagement of attention. Attention does not stay longer at any location unless the task demands are too heavy. Even if some stimuli capture our attention in a bottom-up manner, we can use control to move attention endogenously to newer objects or locations of interest. Therefore, attentional selection to objects of interest is under top-down control. Chun, Golomb, and Turk-Browne (2011) used “internal” and “external” attention as labels to suggest these endogenous and exogenous forms of attention. Humans are capable of deploying attention to any stimuli in a top-down manner when they wish to focus on those very stimuli and not others. Therefore, selective deployment of attention in a goal-driven manner is under executive control. A central question which I address later is whether bilinguals have more top-down or bottom-up forms of attention? We will see that theorists have offered contradictory viewpoints on this issue.

One of the foundational functions of attention is its role as the gatekeeper to our conscious experience. Attention filters stuff out that otherwise will baffle us and distract us from a relevant course of actions. Whether attention filters these distracters early on or much later in the processing stream has been debated for years (Broadbent, 1982). Attention filters anything that is not as per the current goals. If attention can be engaged fully to one object or a location at a time and no other this shows that it is being limited in capacity. For example, when two stimuli are presented in quick succession, the second stimuli is often processed poorly. This has been termed as attention blink (Shapiro, Raymond, & Arnell, 1994). The usual explanation has been that attention has to be free from the first stimuli in order to process the second stimuli, although some researchers have proposed that attention may not be that limited in capacity (Olivers & Nieuwenhuis, 2005). Similarly, studies with multiple object tracking show that participants can keep track of the movement of many objects in their visual space (Pylyshyn & Storm, 1988). However, these may be social circumstances and the more commonly accepted view is that selective attention is pretty limited in its capacity. One can, of course, say that the dispersed state of attention (a global state with broad aperture) can be deployed to process many objects simultaneously. However, for more vivid and objective processing of any one object, selective attention has to be deployed to that very object and no other. It is this view that I will adopt while explaining mechanisms and data in this chapter.
7.2 Visuospatial Attention, Eye Movements and Action

Eye movements during cognitive processing offer clues about a range of issues. Bilingualism researchers have used eye movement tracking as a method to study both language activation (Blumenfeld & Marian, 2011, 2013; Mishra & Singh, 2014, 2016) and cognitive control (Singh & Mishra, 2012, 2013, 2015a, 2015b, 2016). Eye movements reveal attentional mechanisms as well as perceptual processes (see Just & Carpenter, 1976; van Zoest, Van der Stigchel, & Donk, 2017 for reviews). Selection of an object in space, its attentional deployment and its processing reflect in the spatial and temporal aspects of eye movements. It has been suggested that attention and oculomotor programming are intricately related (Rizzolatti, Riggio, Dascola, & Umiltá, 1987). For example, the premotor theory of attention (Rizzolatti et al., 1987) considers attentional engagement to be synonymous to the activation of an oculomotor programme to that location. However, others have proposed a dissociation between attention and oculomotor programming (Smith & Schenk, 2012). For example, the costs and benefits in the Posner’s cueing paradigm were independent of eye movements. Participants could orient spatial attention covertly without making an overt eye movement. Eye movements themselves are under both top-down and bottom-up control. They can be goal directed or stimuli driven. Visuospatial attention is a key mechanism that allows movement of attention in space. Therefore, compared with manual data, eye movement data can provide more direct information about the nature of attention and its relationship to cognition. Singh and Mishra (2012) provided the first robust evidence of language proficiency on oculomotor control in bilinguals.

Visuospatial attention is the key ability that allows us to shift attention at will to objects in space, detect them, act on them and then move on to newer objects. A well-defined fronto-parietal network subserves the movement of spatial attention (Corbetta, Miezin, Shulman, & Petersen, 1993). The popular assumption in the field is that visuospatial attention moves like a spotlight across the visual field. Goal-relevant objects are selected for further processing and execution of actions. Imagine a room full of people and you want to speak to a particular person—your visuospatial attention should be deployed to that person. One standing controversial issue has been is whether this spotlight is location or object based. Duncan (1984) has argued that visuospatial attention is object based. However, others think that visuospatial attention operates in the spatial domain, albeit objects can occupy distinct locations (Lavie & Driver, 1996). Cave and Bichot (1999) suggested that it is not clear if the spotlight of attention is the spotlight for selection, action, filtering or all of these. It appears that there are different subsystems of visuospatial attention that perform various functions depending on the task. However, the concept of visuospatial attention connects strongly to our conceptualisation of action for selection. It is very relevant in the context of bilingualism and control.

One critical function of visuospatial attention is also action selection. One can say that selecting an object in space would amount to some computation on actions that can be performed on it. In his many significant works on the nature of attention
and control, Allport linked the action control system with attention movement. The neural mechanism of action selection and attention are linked (Allport, 1993). Patients suffering from visual neglect fail to exert action in one visual field as they have no consciousness. Allport’s review took the discourse away from the traditional concerns such as early versus late and limited processing views to more action-oriented views. As Mesulam (cited in Allport, 1993) suggested, if the brain had an infinite capacity for processing all kinds of stimuli then there would be no need to have selective attention. Theories of dorsal and ventral streams of visual processing link action control differently (Goodale & Milner, 1992). Therefore, whether attention is of limited capacity or not, whether it is for selection or not, it certainly has a special role in our execution of the goal-directed action. This is relevant to our discussion of how bilinguals may need attention for language selection. Imagine a bilingual who stays in a largely monolingual social world as opposed to a bilingual who finds himself amid a mixture of bilinguals and monolinguals. Need for specific attentional selection is different for the two contexts. This may also have an influence on the internal selection of the interlocutor and language.

Which view of attention have bilingualism researchers adopted most commonly? One finds both the ‘selective attention as a limited resource view’ and the ‘selection for action view’ very prevalent among researchers. Those who have used a task such as the Stroop used selective attention as a mechanism that mediates performance. Although Stroop is a task that measures conflict, one has to also select the right aspect to focus (colour). The selection for action view has not found many applications, at least among those who have studied the question of bilingualism and advantage. Do bilinguals select better than monolinguals? If this is the question then we should bother more about the mediating role of attention in action selection. If language selection for an interlocutor is conceptualised as an action, then the role of attention becomes that of a causal agent. Of course, this view does not conflict with the ‘limited resource’ view as such. Norman and Shallice (1986) noted, “Much effort has been made to understand the role of attention in perception; much less effort has been placed on the role attention plays in the control of action” (p. 1). This also has implications for our understanding of those actions that require deliberate attentional involvement and those that are automatic. In the context of bilingualism, we still do not know how the practice of bilingualism modulates controlled and automatic actions differently. Do highly proficient and fluent bilinguals develop more automatic action selection and control systems that they use for language selection or distractor avoidance? At times it may appear that most actions become effortless for the expert and do not consume much attention (Bruya, 2010).

Hommel (2010) noted that “attention not only subserves action-control processes but may actually have emerged to solve action-control processes in a cognitive system that relies on distributed representations and multiple, loosely connected cognitive streams” (p. 121). According to him, attention is necessary for performing actions—attention helps in intentional selection of actions that the agent has to perform. This sensorimotor view of attention binds the agent and his actions with attention. These views bring attention closer to our consciousness and planning of actions. The problem in the bilingualism cognitive control literature so far, at least
that which has used attentional paradigms to examine group difference, is that a very limited view of attention has been taken. Attention is a name given to a collection of mental processes that subserve different functions. These functions may include selection, filtering, action planning, consciousness, and so on. As for understanding the bilingual question, I think if conscious decisions of language selection and switching are seen as actions that bilingual speakers perform all the time, this sensorimotor action-oriented view of attention will offer better insights.

The data that are discussed in Chap. 6 showed that language selection for bilingual speakers in a social communicative context is not an isolated action. Such action selections are performed with full knowledge of their action’s outcome. Experiential knowledge of our actions and their outcomes when executed provide crucial support to cognitive control. Theorists such as Hommel and others, therefore, are looking for a causal link between intentional states, action selections and agents’ own understanding of their outcomes (Hommel, 2017). The model by Green (1998) referred to inhibition that is controlled by a general purpose executive control. However, we also need to know how actual agents decide to apply inhibition and in which circumstances. In summary, tremendous potential lies in using the various contemporary models of attention and executive control, including theories of action to study bilingual cognition. So far, the few studies that have examined attentional differences between monolinguals and bilinguals have either studied selective attention or visuospatial attention (Friesen, Latman, Calvo, & Bialystok, 2015; Mishra, Hilchey, Singh, & Klein, 2012). Since the adaptive control hypothesis shows promise in explaining the origin of control in social interactional contents, the action-based theories of attention will provide a perfect ground for such theories to flourish. In the following sections, I discuss those studies that have examined whether bilinguals and monolinguals differ in their attentional abilities. I also discuss studies that have used eye movements separately.

### 7.3 Attention, Bilingualism and Advantage

The model that Green (1998) proposed referred to the reactive form of inhibition—it did not have any component of selective attention. If bilinguals constantly inhibit the goal-inappropriate response, why should they have superior selective attention? The Stroop task measures selective attention (Logan, 1980). If the interpretation is that people need to pay selective attention to the relevant aspect of the stimuli then they need not assume an inhibition account by default. Thus, proactive maintenance of selective attention on the task-relevant response should lead to good performance on the Stroop task. There will be no need to inhibit the undesired responses. One can use this logic for any other task that involves conflict. Inhibition seems to be a mechanism central to the suppression of the response that is not goal oriented. The key question is whether proactive selection can take care of costly inhibition?

As early as 1992, Bialystok had suggested that selective attention is enhanced in bilingual children compared with monolingual children (Bialystok, 1992). Bialystok
and Martin (2004) used the dimensional card-sorting task and found the bilingual children to perform better. Bilingual children could focus their selective attention on the task-relevant aspect of the stimuli more flexibly than monolingual children. Different components of attention can be more directly measured by visual search tasks. For example, serial or parallel deployment of attention can be explored in simple visual search tasks (Wolfe, 1994). Chung-Fat-Yim, Sorge, and Bialystok (2017) examined whether bilinguals and monolinguals differ on an ambiguous figure-drawing task. The authors suggest that the exact concept of executive control and which tasks measure it is not yet clear, though many researchers have used the framework proposed by Miyake et al. (2000). Further umbrella terms such as ‘cognitive flexibility’, ‘conflict monitoring’ or ‘cognitive adaption’ leave us vague with regard to the exact mechanism or the task that can tap into it. Selective attention is defined as the ability that allows the agent to stay focused on only one goal-oriented task and not others. Bilinguals should have higher selective attention since they need to focus attention on one linguistic form or one interlocutor; they can maintain attention on two different stimuli and flexibly shift between them as per the demand. This makes sense if we look at everyday bilingual communication where they have to keep both languages active in certain situations.

Chung-Fat-Yim et al. (2017) selected a large population of bilingual adults who had a range of first languages. The main task was a series of cards that presented a picture that gradually changed into a different picture. The idea was to see whether there is a bilingual advantage in the recognition of the alternate image as it evolves. The key question was whether selective attention is involved in task flexibility. Bilinguals were better at recognising the alternate image than monolinguals. The authors interpreted this as showing that bilinguals can maintain both interpretations in their mind and thus were able to track efficiently when the original image changed into something else. One can also say that bilinguals can disengage their attention faster to the original image compared to monolinguals. The authors wrote that

Previous studies of language group differences in processing have used executive function tasks that assess such components as inhibition or working memory. Those studies have produced mixed results, possibly because those components do not define crucial differences between monolingual and bilingual cognition. The present study used the ability to selectively attend to visual stimuli and disengage from the focus of attention to find a new interpretation. This ability certainly involves executive functioning but is not equivalent to it and is not defined by its components, such as inhibition. This ability is similar to the ongoing linguistic challenge faced by bilinguals—namely, to selectively attend to the target language, focus on the correct lexical structure, and disengage as necessary to instantiate or interpret meaning through new structures. The present results are consistent with the interpretation that it is these attentional abilities, notably selective attention, that are shaped by ongoing bilingual experience.

Attention plays a key role in figure-ground processing in case of ambiguous figures (Brugger, 1999). For such figures perception varies between two different alternatives. The duality of perception in these ambiguous figures emerges when one selectively attends to another aspect of the image. Does bilingualism influence this maintenance of the dual perceptual content in such figures? Bialystok and Shapero (2005) administered several figures that had two interpretations. For
example, a picture that at times looks like a rat and an old man or one that changes between faces and a vase. The idea was to see whether bilingual children were better at keeping this separate perception in their mind while they viewed the pictures. The results confirmed that bilingual children could keep the alternative interpretation in mind. Or they could know when such a representation started to emerge and could disengage attention from the original interpretation. Attention disengagement is important for bilinguals in order to facilitate language planning.

7.4  Attentional Disengagement

Given multiple interlocutors in the communicative context, bilingual speakers should know how to disengage attention faster and also deploy faster to relevant ones. Mishra et al. (2012) examined the attentional disengagement using the Posner’s cueing task. They took Hindi–English adult bilingual speakers who differed in their second-language proficiency. Previous studies by Mishra and colleagues had shown that second-language proficiency in unbalanced bilinguals could predict performance on executive control tasks (Singh & Mishra, 2012, 2013, 2015b, 2016). The Posner cueing task tests attentional orienting and also disengagement. First, a very brief peripheral cue appears and then a target follows. Sometimes the cue predicts the location of the target and at other times it does not. Participants are explicitly instructed to discriminate the targets and not to expect its appearance based on the cue. The general finding in such a task is that if the target appears soon enough (within 100 ms) after the cue at its place, then performance is facilitated. However, if the target appears after a delay (after 250 ms or later) responses start to slow. This slowness has been termed inhibition of return (IOR) (Klein, 2000), which refers to the attention’s reluctance to return to a recently attended location. However, this task also reveals the fact that attention is quickly disengaged from a location after a brief period of engagement. This orienting–engagement–disengagement cycle continues. Klein (2000) refers to this as our evolutionary foraging need to bring novel information into our consciousness; therefore, attention is always mobile. However, this mobility of attention can be top-down. We can wilfully move attention from one location to another. Mishra et al. (2012) reasoned that bilinguals with higher second-language proficiency should be able to disengage attention faster from an object than low proficient bilinguals. The results showed that such bilinguals were, in general, faster, but they were also faster in attentional disengagement. This manifested as an earlier appearance of IOR (Fig. 7.1).

Colzato et al. (2008) administered a stop signal task (which measures inhibition), a cueing task (IOR) and the attentional blink (AB) task. Their main argument was that bilinguals and monolinguals might not differ from one another only on inhibition—it is their ability to keep goals in active consideration and execute them while avoiding distractions that give them the cognitive edge. The authors found no group difference in the stop signal task. This indicated that bilinguals and monolinguals may not differ on inhibition. The task to measure IOR was the regular Posner cueing
task. The argument was that bilinguals should show more pronounced IOR than monolinguals since bilinguals must have trained their systems to inhibit languages that they have just attended to. Colzato et al. (2008) did not find any difference between the groups on the magnitude of IOR. The authors also administered the AB task, which measures attentional capacity to process two stimuli in quick succession. If the first target in an AB task occupies the attentional system, then participants make more errors in identifying the second target. The group comparison showed that the bilinguals had a more pronounced AB effect than the monolinguals. Khare, Verma, Kar, Srinivasan, and Brysbaert (2013) had previously found that high proficient bilinguals differed from low proficient bilinguals on the AB task.

The studies by Mishra et al. (2012) and Colzato et al. (2008) differ in their findings on IOR. Both conceptual and methodological issues may have led to these discrepancies. Colzato et al. (2008) took participants who spoke many different types of first languages. Thus, their group was very diverse in their experience of bilingualism. Mishra et al. (2012) compared two types of bilinguals with second-language proficiency as the variables, whereas Colzato et al. compared bilinguals and monolinguals. The targets in Mishra et al. appeared horizontally but in Colzato et al. they appeared vertically. However, a more recent cross-cultural replication of this phenomenon by Saint-Aubin et al. (in press) comparing French–English bilin-

Fig. 7.1 Plot of RT (upper panel) and cueing effects (lower panel, invalid RT – valid RT) as a function of language proficiency and cue-target SOA. Inhibition of return was observed more rapidly for high proficient bilinguals (at 200 ms SOA) than for low proficient bilinguals (at 400 ms SOA) (Mishra et al., 2012). RT reaction time, SOA stimulus onset asynchrony
guals in Moncton, New Brunswick, Canada did not find any relationship between bilingualism (proficiency) and IOR. The non-replicability is not that big an issue in this context. These studies at least helped move the focus from inhibition as the only account.

In this section, I have shown that bilingualism may influence one or another aspect of attention. Attention itself is not a unitary system but is made up of many subsystems. Focusing on attention has more theoretical scope since attention is involved in many conflict tasks anyway. Few studies have shown a replication failure on such tasks.

### 7.5 Eye Movements, Attention and Control

Much recent research into bilingualism has used eye tracking as a technique. Has the choice of response system biased our understanding of control and bilingualism? This cannot be ruled out since most studies to date have used manual reaction times (RTs) as their preferred response system. There have been some studies where researchers have used eye movement measures but few have compared manual versus ocular responses (Bialystok, Craik, & Ryan, 2006). If it turns out that ocular responses are better indicators of cognitive control (even when conceptually the tasks remain the same) then the tenor of the debate may shift. I am stressing this since individual manual and ocular RTs differ a lot. Why would a difference between manual and ocular RTs not matter when we are dealing with claims about bilingualism and its effect on attention? The premotor theory of attention assumes mechanistic similarity between attention and eye movements (Rizzolatti et al., 1987). Hoffman and Subramaniam (1995) demonstrated that eye movements implicate prior attentional shifts towards a location. It has been suggested that attentional shifts and ensuing eye movements to that place are served by the same neural network. Eye movements, in addition, may provide richer data on the nature of attention and control.

Eye movements are basic physiological responses that can give rich insights into cognition—they are intimately connected to attention (Rizzolatti et al., 1987). A saccadic response is very fast, whereas manual responses are slow. Saccadic responses may show the unconscious nature of cognitive actions, whereas manual responses include last-minute decision-making considerations. Eye movements, therefore, can provide more fine-grained data than manual responses on subtle attention mechanisms. In this section, I discuss two different strands of eye movement studies to show that the attempts made so far have been fruitful. Eye movements reveal both transient and continuous states of cognition (Spivey, 2008). Buswell (1935) had shown that eye movements reveal the internal states and top-down mental states of the onlooker. Rayner (1998) showed how movements during reading can reveal a complicated interaction between attentional, perceptual and linguistic processes. Then eye–mind hypothesis by Just and Carpenter (1976)
suggested an intricate link between cognition and eye movements. After 1995, eye movements were used to study the online interaction of language and visual processing in a novel paradigm called as the visual world paradigm (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). This paradigm has revealed the online activation of words in the bilingual lexicon during comprehension.

In a first of its kind study with Indian bilinguals, Singh and Mishra (2012) examined how high and low proficient Hindi–English bilinguals differ in inhibitory control in an oculomotor Stroop task adapted from Hodgson, Parris, Gregory, and Jarvis (2009). These bilinguals were university students who had acquired English as a second language early in life. They were rather unbalanced since most of the time they used English in their everyday life. The original authors had shown that words such as ‘up’ and ‘down’ move visual attention in space. These direction words activate an oculomotor programme that then drives eye movements. This reflexive eye movement (attentional shifts) could then be exploited in a Stroop-like situation. The display had four coloured boxes; a direction word written in one of the colours appeared at the centre. The participants were asked to make an eye movement towards the box similar in colour to the written word. Classically, the Stroop effect arises when readers automatically activate the semantics of the word irrespective of the colour and this activation then leads to interference. This conflicts with the goal-directed response that the task imposes. The authors expected that participants would face conflict when they activated the word’s meaning automatically and that this would cause interference with the programming of the saccade. The results showed that high proficient bilinguals were faster in programming a saccade, irrespective of this conflict. It was the first evidence of a bilingual advantage in an oculomotor task.

This study showed that one can use oculomotor responses to examine whether bilingualism modulates executive control. The authors had also noticed an overall speed advantage for the high proficient bilinguals. This was then interpreted as superior executive control, as proposed later by Hilchey and Klein (2011). The novelty beyond its interpretation was the use of ocular responses. These responses were not contaminated like manual responses and truly represented attentional involvement. At that point in time, there were few studies that directly referred to attentional control in bilinguals in an eye movement study. Later in a follow-up study, Singh and Mishra (2013) examined whether monitoring demands modulated such conflict resolution in this eye movement task. Costa, Hernández, Costa-Faidella, and Sebastián-Gallés (2009) had shown that bilinguals brought in superior executive control only when the context was demanding. They manipulated this by mixing congruent and incongruent trials in different percentages. The argument was that when the incongruent and congruent trials are equally mixed as opposed to when one type of trial was greater in number, uncertainty is higher; participants cannot adapt to any strategy and more demands are placed on the executive control system. Singh and Mishra (2013) used the same logic and manipulated the trials. The stimuli were similar to in the Singh and Mishra (2012) study, except in place of written words they used symbolic arrows. These arrows are known to drive attention reflexively since they are over-learned symbols indicating direction (Ristic, Wright,
The expectation was that high proficient bilinguals would use higher executive control when the congruent and incongruent trials were equal in number and that this would reflect in their performance on the Stroop task. They were asked to programme a saccade towards a colour patch that matched the colour of the central arrow. It was assumed that the direction of the arrow would lead to a reflexive saccade towards a different colour patch. In order to do well in the task, participants needed to inhibit this response. The results showed that when the context was more demanding the high proficient bilinguals were better at managing the conflict and were also faster in their saccade latency. Both studies found an overall speed advantage for the high proficient bilinguals, which indicates superior executive control apart from inhibition.

Extending their approach of using eye movements as dependent measures, Singh and Mishra (2016) examined whether high proficient Hindi–English bilinguals were better at the anticipation of a response. Saccades can manifest anticipatory processing much before stimuli have appeared. Singh and Mishra (2016) used a novel task which required participants to control their saccade preparedness. The stimuli figure (Fig. 7.2) shows the stages of processing that were required. It is well-known that saccade preparation takes around 200 ms in normal situations. Once a saccade has been programmed and sufficient time has passed then it has to be executed (Logan, Cowan, & Davis, 1984). Participants were asked to only make a saccade towards the target when they saw the orange circle. Interestingly, the orange
circle stayed for a variable time. This uncertainty affected saccade preparation. The authors hypothesised that preparing a saccade and executing it under uncertainty may require executive control. The high proficient participants may be better at this than the low proficient bilinguals. The results showed that the high proficient bilingual had higher anticipatory saccades and also committed fewer errors. The anticipatory saccades were saccades with very fast latency (<200 ms). Very fast saccades after the onset of the orange light onset may emerge only if the participants have already prepared the saccade but waited for the orange signal. The saccades could be initiated faster (<200 ms) since their saccade preparation was complete when the orange light came on.

A long-running idea in the bilingualism executive control literature is that bilingual advantage is observed under extreme task demands and that this advantage can be tracked with methods that are subtle enough, such as through eye movements. More recently, Ratiu, Hout, Walenchok, Azuma, and Goldinger (2017) examined performance in bilinguals and monolinguals on a visual search task with various difficulty levels. Crucially, they measured eye movements as they capture fine-grained information revealing aspects of attentional control. The authors argue that global measures such as RTs and accuracy in traditionally administered visual search tasks do not reveal fine-grained processing differences that may exist between bilinguals and monolinguals. The task was a conjunction search where the target to be searched resembled many other distracters in one or more features. This type of search has been shown to be very demanding for selective attention. Of course, it is not known if one has to selectively focus on the target or inhibit the distractors to be successful in this search task. The authors’ use of eye movements as variables with regard to different states of search and their links to bilingual control is worth noting. In their hypothesis they wrote that “If a bilingual search advantage arises from more efficient attentional guidance, bilinguals should show faster first fixation times to targets, relative to monolinguals. If a bilingual advantage arises from more efficient response initiation, bilinguals should have faster decision times (latency from the first fixation to the keypress) than monolinguals. If the advantage arises from a combination of these processes, then bilinguals should show faster overall search RTs (latency from trial onset to the keypress).” The results showed that bilinguals are not that different from monolinguals in gross measures such as total search time. They had a slight advantage in decision-making, reflected in fixations preceding a manual key press. These experiments show that when task difficulty rises, bilinguals may bring in executive control to deal with it.

Which attention task best captures bilingual advantage? From the description of the myriad studies, it is not clear. I have shown that eye movements as a measure are more subtle and can help us learn more about decisional processes. Very few have used such methods to examine the subtle differences that may be at the heart of this whole debate. After all, bilinguals and monolinguals may not be that different in their attention and executive control performances. The tendency among researchers has been to use novel tasks and propose linking hypotheses that support some predictions. However, how far the hypotheses themselves are grounded in the psycholinguistic underpinnings of the issues requires more clarity. For example, which
psycholinguistic behaviour of a bilingual enables us to say that they are faster only at the decision-making stage of attention allocation in a visual search task? Given the state of affairs, it is important to consider these data as they cast new light on the mechanism involved. In Sect. 7.6 I discuss some studies that have used the visual world studies that link executive control with parallel language activation.

7.6 Language, Vision, Attention and Control

Bilinguals activate both of their languages in parallel. Does executive control mediate parallel language activation in the bilinguals? It should since the enhancement of executive control depends on managing language non-selective activation. Although many have shown that bilinguals always activate words in both their languages even if they need to just speak in one, it is not known how they manage to bring down the activation. I am not going to review the many studies that proliferated after the first studies by Spivey & Marian (1999) that used eye tracking to show language non-selective activation in bilinguals (Blumenfeld & Marian, 2007; Ju & Luce, 2004; Marian & Spivey, 2003; Weber & Cutler, 2004). Since the visual world paradigm studies how spoken words move attention to visual objects, it can be used as a model to study executive control-related issues in bilinguals. It also extends the debate to cross-modal data. The visual world paradigm requires swift integration of linguistic and visual representations (Mishra, 2009).

Marian and Spivey performed many experiments with Russian–English and other bilinguals using visual world experiments (Marian & Spivey, 2003; Spivey & Marian, 1999). The earliest studies showed that when Russian–English bilinguals listen to a word like marka, they also look at an object displayed on the computer screen that is called ‘marker’. This effect was linked to the cross-linguistic activation of between-language competitors. The visual world paradigm captured this subtle activation indirectly as participants only listened to spoken words and saw pictures. Later, others showed such effects in bilingual groups found in countries such as the Netherlands (Weber & Cutler, 2004) and India (Mishra & Singh, 2014). All these studies showed that, irrespective of the level of bilingualism and languages, all bilinguals activate words in parallel. This was taken to be one of the most important hallmarks of bilinguals’ semantic memory system. In an unusual design, Singh and Mishra (2015a) demonstrated that such non-selective activation could interfere with saccade programming; Fig. 7.3 shows a sample trial from this experiment. Participants saw four objects on the computer screen and heard a spoken word. One of the objects’ names was a phonological relative of the translation of the spoken word. For example, participants listened to the English word ‘ring’ (angoothi in Hindi). The display contained the picture of ‘grapes’ (angoor). The critical manipulation involved a sudden change in the border colour of one of the objects. The viewer had to make a quick saccade towards this picture, which changed colour. The cross-linguistic competitor interfered with goal-directed saccades. Participants were slow as their attention was captured by this object.
Bilinguals activate translation equivalents (Marian et al., 2003). The well-known translation recognition task shows that bilinguals delay rejecting a non-word when it is related to the translation of a primary word (e.g. Sunderman & Kroll, 2006). Sunderman and Priya (2012) have shown this in many experiments. Mishra and Singh (2014, 2016) used the visual world paradigm to examine whether Hindi–English bilinguals activate translation equivalents of spoken words when they listen to just one language. These experiments presented displays that had a picture which was a phonological cohort of the translation equivalent of the spoken word. The data show that bilinguals quickly oriented their visual attention towards this picture with the onset of the spoken word. Such evidence suggests that bilinguals activate words in the other language that are related in phonology as well as meaning. Attention in the visual world paradigm is oriented automatically towards such objects. Does executive control play any role in constraining such eye movements? Why should attention be moved spontaneously towards objects that are not targets of processing?

Fig. 7.3 Participants were asked to make a saccade to the target object that changed colour. Here, spoken word ‘ring’ (angootha) was presented and the display consisted of a phonological cohort of angootha: angoor (grapes). Participants were slower in making the saccade to the target in the presence of such a phonologically related object.
There have been few attempts to link inhibitory control to eye movements in the visual world paradigm. However, researchers who have studied monolinguals using the visual world paradigms have claimed such eye movements to be automatic in the classical sense that these eye movements are beyond volitional control and attentional control (Salverda & Altmann, 2011). More recently, however, it has been shown that such eye movements are linked to working memory capacity (Huettig & Janse, 2016). Working memory is synonymous with selective attention in the current theorisation (Gazzaley & Nobre, 2012). Since bilinguals are supposed to have greater executive control, it is intuitive to propose that such eye movements will be constrained better in them. Or, alternatively, performance on the executive control tasks should correlate with the proportion of fixations in the visual world task. Blumenfeld and Marian (2011) presented phonological competitors of spoken words on a display and measured eye movements. They further measured performance on the Stroop task. They wanted to see whether bilinguals were able to suppress the activation of competitors during language comprehension. Only bilinguals were able to inhibit the cross-linguistic activation as seen in the negative priming. The authors suggested that bilinguals use inhibitory control to suppress task-irrelevant word activation. A similar attempt was made by Mercier, Pivneva, and Titone (2014) where they collected oculomotor measures on executive control. Participants performed a visual world task and their eye movements were measured to quantify cross-linguistic and within-language activation. Bilinguals with superior executive control on the oculomotor tasks were also better at resolving the cross-linguistic activation faster. Performance on the oculomotor inhibitory control task (anti-saccade task) correlated with lexical activation. This study points to a few interesting things. Domain-general executive control mechanisms influence lexical activation and eye movements in the visual world task. Since the visual world task exploits linguistic activation but measures eye movements to visually presented objects, an ocular measure can predict performance in this task. Even if parallel language activation is the norm for the bilingual brains, disengaging attention from the competitor pictures is achieved through executive control. These studies also bring to focus the role of selective attention in the integration of visual and linguistic activation.

It is also important to note that most replication failures have reported manual data. I am of the opinion that if the same tasks are performed with ocular data then the results will be different. For example, not a single study (to my knowledge) has produced null results with a visual world paradigm tracking bilingual lexical activation. Of course, bilinguals in different cultures (compare Mishra & Singh, 2016 with Weber & Cutler, 2004) show activations in different language directions. In contrast to studies that have replicated manual studies and have failed to get any effect, these studies have measured both manual and oculomotor data. Therefore, it will be interesting to see replications of such eye tracking studies. The reason why bilinguals should be more sensitive to visual cues is linked to their developmental histories. As infants, they learn to link different faces with different languages. These faces help them select the correct languages.
7.7 Attention, Culture and Bilingualism

Textbooks on bilingualism generally do not have a chapter linking bilingualism to culture. Cognitive psychologists have consistently avoided cultural variables that affect critical systems such as attention, working memory and inhibitory control from their modelling and discussion. However, when it comes to the practice of bilingualism and its effect on cognition, I think it is important to see if known cultural attributes of a population influence our experimental outcomes. Cultural attributes of the people and their ethnicity (i.e. Chinese vs. American) influence their attentional systems. Many studies that have compared different ethnic populations on cognitive tasks have shown profound differences on performances (e.g. Masuda & Nisbett, 2001, 2006). Bilingualism itself may vary from one country to another. Are bilinguals in France similar to bilinguals in India? If they differ on many known variables, many of which are cultural and also linguistic, then how can one expect any replication of experimental results? Bilinguals in different cultures may differ in habits of switching, use of dialects, use of multiple scripts, known preferences of a language to particular interlocutors and many other social–contextual factors. A critical survey of research papers that have studied, for example, how bilingualism influences selective attention or executive functioning will show that not many have considered these aspects. Rather, recently many researchers have clubbed together bilinguals who have many different first languages in a single group. If all of them do not have a similar personal history of switching, shifting and monitoring, then how can they be clubbed into a single group? In this section, I address only the issue of cultural influences on attentional allocation, on which many studies have been carried out.

If cultural forces influence core cognitive systems such as attention, independent of language then how culture-neutral is our analysis of executive control tasks? It appears that people from different cultures deploy attention differently to visual stimuli. Eye movement studies show this difference to be present in many tasks of visual exploration and search. For example, Alotaibi, Underwood, and Smith (2017) compared British and Saudi Arab nationals on a comparative visual search task and recorded eye movements (Fig. 7.4). The British are known to come from an analytic type of culture that values individualism. This leads to higher selective attention to individual objects. The Arabs are a collectivist culture and deploy a more dispersed attentional processing style. Alotaibi et al. (2017) recorded eye movements as participants searched objects either presented focally or in the background. The authors manipulated these objects to see how long it takes the participants to figure out the change. The expectations were that the participants with a more focal individual attentional allocation should be good at finding change when the object was presented focally. Those who came from the collectivist culture should perform well when the objects are in the background. The results showed that Arabic nationals were slower in their search times and the British were faster in finding objects when it was presented focally. The authors did not find any group difference in search style. It has been shown previously that easterners show more contextual processing.
than westerners in visual search tasks (Masuda & Nisbett, 2006). In another early
eye tracking study, Chua, Boland, and Nisbett (2005) had shown that Americans
deploy more attention to the foreground than background. This difference in atten-
tional strategy was linked to their individual cultural background.

Why does this matter in the context of bilingualism? Whether one is bilingual or
monolingual, everybody belongs to a certain cultural group. The cognitive process-
ing style associated with that group will affect how this individual looks at and
attends to information. Thus, both bilinguals and monolinguals in a culture will have
a certain style of processing compared with other bilinguals and monolinguals who
come from a different culture. Over and above this, bilingualism per se may influ-
ence attentional allocation in such individuals differently. Therefore, when we are
comparing, for example, Chinese–English and English–Spanish bilinguals cross-
culturally, our result will have traces of cultural contribution. The studies that I have
cited here and many others have compared bilinguals with monolinguals. Two groups
of monolinguals who come from two different cultures already differ on attentional
tasks and visual scanning. It is important to note that in this discussion, I am not
interested in the differences between bilinguals and monolinguals but between two
groups of bilinguals who represent two distinct cultures. Their individual cognitive

Fig. 7.4 Sample stimuli images from Alotaibi et al. (2017). Participants made a judgment on the
focal objects in the upper panel. The lower panel is an example of a trial where the background
object was the target.
styles of processing will directly influence any attentional tasks administered. Therefore, cultural factors extraneous to bilingualism should be looked at carefully before we make statements on replication failure or null effects.

Let us take an example and see how individual cultural styles of processing may affect bilinguals’ language selection in a communicative context. It is now recognised that bilinguals keep track of their interlocutors and select languages appropriately (Green & Abutalebi, 2013). Is this selection contingent on the bilingual speaker’s specific culture-induced attentional processing style? How do two bilinguals that come from analytic versus collectivist (holistic) cultures differ in terms of their attention to, for example, interlocutors? Suppose there is a picture that shows an interlocutor in the foreground and the background has some other interlocutors. Further, suppose that the languages that this focal interlocutor speaks and those in the background are different. Assuming that cultural forces affect how one processes the foreground and the background images, it is possible that some bilinguals are going to face higher conflict in language selection because of the background pictures, particularly when the language that the speaker tags with the interlocutors in the background is incongruent with the language he tags with the interlocutor in the foreground. If we compare Chinese–English bilinguals from Beijing and English–Spanish bilinguals from the USA, the former bilinguals are probably going to be more sensitive to the background interlocutors. This sensitivity may influence their perception of conflict during language selection.

Culture also modulates the development of executive control. It is important to recognise that most initial studies that showed a bilingual executive control advantage were on children (Bialystok, 2001). There has even been the suggestion that children are the best candidates for manifesting the bilingual advantage. Since adults already operate at a peak, one cannot know if the advantage in them is because of bilingualism or more general resources. Roos, Beauchamp, Flannery, and Fisher (2017) wrote that “From a sociocultural perspective, investigating how EF [executive function] is influenced by culturally variable environmental factors could establish the key “ingredients” through which individuals’ behaviour comes to reflect their culture. From a cognitive science perspective, identifying mechanisms through which environments shape developing brains would help explain individual differences in EF and inform assumptions about the universality and diversity of “normative” development. Current EF research rarely includes assessments of culture, and cultural research typically does not incorporate measurement of EF.” This means that unless we look at the cultural underpinnings of the various executive control process our group differences on bilingualism may not be informative. In their meta-analysis of the executive control literature, they observe that East Asians show superior performance on executive control tasks compared with westerners. However, this difference is not always consistent across tasks. Let’s take one example where cultural differences in second-language learning at school are evident. In India children acquire English pretty early at schools, much earlier than in China; of course, India’s colonial history is responsible for this as India has many more schools that teach English early on than in China. In addition, cultural attitudes towards learning English may be different between Indians and Chinese. When a
study compares such bilinguals, it is important to consider such factors. Similarly, in many studies that have taken bilinguals from different European countries with English as a second language, it is important to consider the L2 learning mechanism. For example, the status and spread of English in the Netherlands is not similar to what one finds in Spain. Therefore, both educational and pedagogical history and cultural values towards language acquisition and use are important when accessing groups and their differences on executive control tasks.

7.8 Summary

In this chapter I have explored how attention could be the key to understanding the bilingual cognitive advantage question. Data from attention tasks administered manually and visual world studies indicate several dimensions to the bilingual question. Bilinguals show extreme language non-selectivity during language comprehension. Presumably, their need to exercise executive control arises as a result of curbing such continuous interference. It has also been noted that there is currently a trend towards moving away from a hard inhibitory control account. Researchers are searching for differences in attention tasks. Studies on attention using eye tracking have revealed more fine-grained data.

References


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References


8.1 Summarising the Facts

When I started writing the book, almost a year and a half ago, it appeared as if there would be no further interest in the bilingual cognitive advantage question. A few replications had failed and their authors had taken very strong stand against the whole field. There were also allegations of publication bias in major psychological journals. However, the researchers supporting the advantage debate have also responded to all these charges. These responses and rebuttals revealed how, at times, we are very eager to demolish a field just because some authors could not replicate the findings of others, particularly when the replications are conceptual and not direct. It is important to note that by today’s standards even replications should be challenged for their methodological accuracy and motivations. Of course, many studies that have obtained positive results could be problematic for many reasons. The tendency to obtain significant statistical differences with small sample sizes still remains very popular in psychology. Alternative statistical procedures at times can eliminate some problems. However, even replications that challenged the positive results may have these problems. Nevertheless, in this chapter I cite some authors who have reviewed the field in last few years and explore whether they are positive about the field’s continuation or they think it has no further scope. Of course, the naysayers will cast doom since they think bilingualism does not affect executive functioning anywhere, no matter the case. Both positive and negative results should be closely examined to separate the facts from their interpretations. I am of the opinion that at times we gloss over our results and make claims that are problematic since bilingualism has not been studied in its entirety and many fundamental loopholes in methods and participant selection remain. Before I get into these points, I try to summarise the issues presented in the other chapters.

In Chap. 2, which was on the evolution of bilingualism, I pointed out that unless we know how such an amazing trait has evolved in *Homo sapiens*, we may not know how to understand it fully in its current state. Studies in cognitive archaeology and
related disciplines are currently unearthing empirical facts about the evolution of human cognitive abilities. It is one thing to talk about how language might have evolved and another to describe the evolution of bilingualism. Since the very cognitive control mechanism that handles two languages has a short evolutionary history, it is important to know how humans learned to manipulate two languages in vastly different social and linguistic situations. Cognitive archaeologists have performed experiments to understand when important cognitive systems such as working memory and selective attention might have evolved in humans. How did the brain became neurologically and cognitively fit to manage two languages? This is, of course, a chicken and egg problem, but the question cannot be dismissed as unimportant. I suggested that although much research focus has gone into understanding the evolution of language as such, very little work exists on the evolution of cognitive mechanisms. Further, I elaborated that the evolution of bilingualism could be deeply rooted in our shared social and cultural evolution.

Today, because of geopolitical considerations in many locations around the world, bilingualism is either promoted or rejected. During times of growing nationalism and social groups, multiculturalism is at risk. And with it, the opportunity to and interest in learning and using two languages is also receding. If evolutionarily we are geared to mingle with others, cross boundaries and adapt, then bilingualism is a crowning achievement for the cognitive system. Its economic benefits are secondary. In this spirit, we should learn more about its evolution in our species. We could not have become bilinguals unless we evolved to consider one another’s language, learn it and use it consistently. Whatever economic or social reasons may lie behind learning another language is another matter. Brains equipped themselves with this ability so that any human child who is exposed to more than one language can learn them. The problem with the current enterprise of the study of language evolution is that it is either too focused on its computational characteristics or on the articulatory systems. It is time to look at the evolution of the cognitive systems that made all of this possible.

Chapter 3 explored the main theoretical undercurrents fuelling current research into bilingualism. Bilinguals translate the words they encounter to different degrees and also activate words that are related cross-linguistically. Various models such as the revised hierarchical model (RHM) (Kroll & Stewart, 1994) and bilingual interactive activation (BIA) model (Dijkstra, Van Heuven, & Grainger, 1998) have made predictions regarding such activations during bilingual language processing. While one model has focused on the developmental trajectory of second-language acquisition and the growth of competence in handling that language, others have focused on the nature of language non-selective activation. Translations of words in the bilingual’s lexicon represent two different phonological structures of the same conceptual element. In many visual world eye tracking studies, Mishra and colleagues have shown that Indian unbalanced adult bilinguals activate translation equivalents during listening to spoken words (Mishra & Singh, 2014, 2016). Such language non-selective activation is also seen when bilinguals see written words. Highly proficient bilinguals are known to access translations of words in their other language. Thierry and colleagues (e.g. Thierry & Wu, 2007) found such activation of
translations to be non-conscious. A critical question is whether bilinguals suppress this information when they wish to focus on only one representation? The functional link between bilingualism and cognitive control is related to this continual suppression and selection. I also examined how inhibition, switching, monitoring and attentional disengagement affect bilingual language control. Reactive and proactive types of inhibitory control suggest a role of individual differences (Braver, 2012). Further, language switching has been extensively studied as it is related to language control. Switching has been shown to engage the frontal areas of the brain.

Bilinguals monitor both their environment and also their languages. Monitoring is a key cognitive activity when one engages with multiple attention-demanding tasks. In the bilingual context, monitoring is linked to selection of the correct language for the particular interlocutor. Monitoring demands have been linked to engagement of executive control (Botvinick, Braver, Barch, Carter, & Cohen, 2001). The adaptive control hypothesis projects monitoring as a key feature of bilingual neural language control (Green & Abutalebi, 2013). However, current research has not thrown light on how monitoring is achieved during everyday language communication. How do contextual factors modulate monitoring and how, depending on their proficiency and executive control, do different bilinguals achieve monitoring? The chapter also included attentional disengagement as a core mechanism that helps bilinguals exercise control. Bilinguals may actually have superior selective attention more than inhibition (Bialystok, 2017). During real-life communication, bilinguals need to disengage from one interlocutor and engage with another. This cycle of engagement and disengagement entails control. Mishra, Hilchey, Singh, and Klein (2012) showed that bilinguals with superior second-language proficiency actually disengage faster from a set task. There are certainly many other mechanisms that are probably fundamental to bilingual language representation and control; however, I selected those around which most researchers have focused on—from the point of views of the psycholinguistic theory of language representation and also the domain of non-linguistic control. The key issue is how dual language management leads to domain-general executive control in the bilinguals.

Chapter 4 focused on the current criticisms against the bilingual cognitive advantage question. A close review of these replications suggests that they may well suffer from methodological issues similar to the studies they were trying to prove as being problematic. I also discussed the question of publication bias that has been at the centre of this debate. The chapter was written to show that not all is well with the bilingualism cognitive advantage question. Does this mean the question should be abandoned without further research? Paap and colleagues (Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2015) have outright denied any cognitive advantage of acquiring two languages. Similarly, Duñabeitia and colleagues (e.g. Antón et al., 2014) also consider that there is no bilingual advantage. Hilchey and Klein (2011)) believe that maybe we do not know the right questions yet or the tasks that will tap into them. The chapter thus indicated that even if there are many methodological issues with the research so far that has obtained positive results, it is not fair for science to drop the research agenda. Later in this chapter, I suggest the domains and issues that should be taken up in order to search for more holistic answers to the

8.1 Summarising the Facts
question. Many recent proposals suggest selective attention and monitoring (Chung-Fat-Yim, Sorge, & Bialystok, 2017; Grundy, Chung-Fat-Yim, Friesen, Mak, & Bialystok, 2017) as important mechanisms. Valian (2015) suggested that it is important to isolate the tasks which measure the specific benefits that bilingualism bestows since there are differences in the cognitive psychological interpretations of tasks such as Stroop, Simon or anti saccade. When authors who report null results and failed replications do not suggest alternative possibilities or corrections to the methodology, then it leaves little space for further research.

Chapter 5 reviewed published research that shows how the bilingual and monolingual neural networks may differ functionally and structurally. A tremendous amount of research has been directed at investigating the neurobiological consequences of bilingualism. It is now well-known that the acquisition of a second language in childhood alters specific brain networks later. On the question of cognitive advantage, research shows that the anterior cingulate cortex (ACC) is involved in conflict management. Research by Abutalebi and colleagues has shown that ACC activation in bilinguals during conflict tasks is different to that in monolinguals (Abutalebi et al., 2011). Hyper- and hypo-activation of such selective brain regions in the bilingual show that, indeed, bilingualism modifies the existing networks, making them more efficient. However, most of the positive results obtained with neuroimaging have not shown up in the behavioural tasks. It is possible that these methods reveal different aspects of the processing of the same stimuli. Neuroimaging research has also revealed how brain networks of the bilinguals keep track of the language of the interlocutors. Neuroimaging methods such as fMRI (functional magnetic resonance imaging), EEG (electroencephalography), MEG (magnetoencephalography) as well as NIRS (near-infrared spectroscopy) track different aspects of the processing and also provide different types of data. Without getting into their unique methodological issues, it is sufficient to say that each method and its data constrain the theory. Not finding a cognitive advantage with behavioural data does not mean it won’t be found with neural data. This is a very important consideration as some researchers have reported a dissociation between neural and behavioural data in their research (see Abutalebi & Green, 2016 for a review).

Chapter 6 discussed the influence of context on bilingualism and control. A context represents the environment in which bilinguals function daily and the variables that affect them. Many recent studies have shown that bilinguals control their language with regard to their interlocutors (Molnar et al., 2015; Woumans et al., 2015). They can visually tag languages of their interlocutors and use this knowledge to select the appropriate language during a conversation. This tagging of language with a human face or a cartoon seems very natural for the bilingual who deals with two or more languages associated with the interlocutor. Further, bilinguals and their listeners are embedded within a large communicative space which may have many types of interlocutors with varying language proficiencies. How does a bilingual speaker keep track of such information? Are bilingual babies born with such knowledge or this an acquired behaviour? These questions remain unanswered to date. However, the data discussed in the chapter suggest that bilinguals consider the languages fit for their interlocutor when they make their own decision. In my own
studies with Indian bilinguals, I have shown that bilingual speakers also consider the relative language proficiencies of their interlocutors (Kapiley & Mishra, in press). If they see a bilingual who has low proficiency in the second language then they shift to the first language in which both are comfortable. Bilingual speakers also show sensitivity to passive interlocutors if they trigger one or the other language. This influence later affects their own language choice (Bhatia et al., 2017). Such adjustment goes beyond mere tagging of languages with the interlocutors but includes dynamic evaluation of which language to be used in particular contexts. The chapter also presented the adaptive control hypothesis (Green & Abutalebi, 2013) and its general predictions. It is the latest addition to the theories that attempt to account for bilingual language control through switching and neural control of language. Different types of bilinguals bring control to different degrees depending on how much they switch. This context-dependent switching behaviour affects the selective activation of the ACC. This proposal has helped shift the debate from a strict inhibitory control account to the domain of contextual and individual differences. It should be noted that how fluently and how often bilinguals switch is also linked to different components of their executive control.

Most cognitive psychological studies on the question of language control in the face of interlocutors use static faces or cartoons. In the real world, interlocutors can change dynamically and without prior information. The studies discussed in Chap. 6 are thus limited if we consider real-life challenges of language control that bilingual speakers deal with. How do they keep track of the social space with constantly shifting interlocutors? This question requires study of language control in real-life situations, which may include using wearable devices and a virtual reality (VR) set-up where speakers immersed within a context choose a language. Unfortunately, as yet simple laboratory-based studies of language production and switching have not taken into account these issues. A model linking this top-down control of language in the face of bottom-up cues and the role of executive control is now necessary. Further, even if bilingualism bestows some advantages in general cognitive control, we have no idea how and which bilinguals use such control in their daily speaking. Do fluent speakers struggle with inhibition during real-life conversations?

Chapter 7 explored how the mutual interaction between attention, vision and language have a bearing on bilingual language processing. Attention, particularly selective attention, has emerged as a key mechanism to explain the cognitive advantage bilinguals may enjoy. In recent studies using various psychophysical techniques, researchers have shown that bilinguals may have superior selective attention (Friesen, Latman, Calvo, & Bialystok, 2015; Mishra et al., 2012). In particular, they also seem to disengage attention from one stimulus and orient it towards another faster than monolinguals (Mishra et al., 2012). Studies using the visual world eye tracking paradigm have produced a range of data that show that bilinguals orient attention towards objects whose names are either phonologically or semantically related to the spoken words they are listening (Huettig, Mishra, & Olivers, 2012; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). Rapid access to both within- and cross-linguistic information seems to be ubiquitous in bilinguals. This strand of research has equivocally demonstrated that language non-selective activation within and across
languages is a norm and automatic in bilinguals. It also demonstrates how swiftly attention is oriented in space with regard to language input. More recently, it has been shown that such activations of cross-language phonological forms may be constrained by working memory (Huettig & Janse, 2016). Further, Marian and colleagues have shown that cross-linguistic activation and its extent is linked to executive control (Blumenfeld & Marian, 2013). Those bilinguals who have superior executive control can control these unwanted activations faster. This is a critical link between bilingual language processing, attention and executive control. It must be noted that selective attention is a core component of the executive functions framework proposed by Miyake et al., 2000 (and is also functionally similar to recent conceptualisations of working memory (Gazzaley & Nobre, 2012)). However, at this point in time, there is not much of a convergence between the psycholinguistic findings related to the attentional mechanism in bilinguals and cognitive psychological studies of attention in bilinguals. Nevertheless, visual world eye tracking studies have the potential to bridge this difference through a linking hypothesis (Tanenhaus, Magnuson, Dahan, & Chambers, 2000). Functional neuroimaging data using NIRS has shown that bilingual children (aged 7–13 years) show greater activations in the left prefrontal areas, whereas monolingual children show greater activations in the right prefrontal areas when they perform a non-verbal attention task such as the Flanker task (Arredondo, Hu, Satterfield, & Kovelman, 2017). Therefore, as one begins to become bilingual, neural synchronisation and specificity increases in the non-verbal attention control domain. Of course, there are also behavioural studies that report null results on any attentional advantage for bilingual children on such tasks (Antón et al., 2014). In such a situation I again reiterate that neuroimaging data and behavioural data cannot be compared to make claims for non-replicability of findings.

Studies of selective attention reveal that bilinguals can maintain two different representations of the same stimuli and swiftly shuttle between them compared with monolinguals. For example, Chung-Fat-Yim et al. (2017) have shown that bilinguals can maintain two different representations of one stimulus better than monolinguals. This is another dimension of selective attention in which bilinguals are better, apart from performing better on traditional attention tasks such as visual search. In Chap. 7, I also suggest that current theorists view attention in connection with action control systems (Gozli & Ansorge, 2016). Goal-directedness of impending action recruits the selective attention system. Language is part of the action control system embedded within the rich sensorimotor framework (Mishra, 2015). Therefore, language use is an intentional act that is achieved through the top-down control networks of the brain. When a bilingual chooses to disengage from one interlocutor and engage with another, he intentionally selects one language and inhibits another. Therefore, if bilingual communication is viewed as a dynamic exercise of top-down goal-oriented action, our view of the role of attention in it also has to be commensurate with it. In this view, attention filters out the items or stimuli in the environment that are not appropriate for the current goal and orients the systems towards the goal-relevant ones. Do bilinguals do this better than monolinguals in general? What role do executive functions play in this? It is known that those who have better executive
control are also better in goal-directed actions. Following this, since bilinguals need to constantly shift between goals, they should exercise selective attention much more than monolinguals who only deal with one type of representation.

In writing these chapters I did not go for the straightforward model of reviewing research findings in relevant areas. Rather, I covered the relevant research in each area as they made sense conceptually. In the following section I explore the future of the field, providing examples of specific areas that need our attention. Negative results or non-replications should not destroy the question; rather, they can be signposts for adjustments and calibration of the hypotheses. This is how I have come to view the field in last few years. While I present my own recommendations for fellow researchers and aspiring graduate students to consider in their research, I also note that, more recently, excellent reviews of important articles have appeared that also profess similar things (Baum & Titone, 2014; Bialystok, 2010, 2017). The conceptual and methodological difficulties that the field is facing is well-known and acknowledged by researchers. In Sect. 8.2 I discuss aspects of the research programme that should be explored while we are answering the question of cognitive neuroplasticity induced by lifelong bilingualism. The long-term sustained practice of any skill does restructure the neural network; however, the key issue is to explain the mechanism of this and define the variables that influence the longitudinal changes that the brain goes through after learning two languages.

8.2 Areas for Future Research

8.2.1 Individual Difference, Executive Functions and Bilingualism

Most cross-sectional studies do not tell us about the developmental trajectories the participants have undertaken in their cognitive skills. Judgments on cognitive differences between two groups, therefore, can be at best ad hoc. Individual difference factors play a key role in shaping how individuals acquire fully functional and competent cognitive faculty later. By the time we test an adult college or university student on a host of executive control and language tasks, he or she has undergone years of changes and learning about which we have no idea. The sum total of many factors—which include cognitive capacity, working memory, motivation, and soundness of the neural structure and its efficiency—exert influence on the tasks one does as an adult. Therefore, cross-sectional data may not be sufficient to settle the debate about advantage. Any practice- or skill-induced neuroplasticity is of a long-term nature. Many studies show that individual difference-related factors such as working memory, motivation, and also prior knowledge and context of learning influence how one acquires and masters a second language (Mitchell, Myles, & Marsden, 2013). When people are fundamentally different in how they are acquire skills, then their performance on any executive control task is also an outcome of that. My point is more relevant for studies that compare bilinguals and
monolinguals. I have indicated before that I am sceptical of such studies since these two groups come with many neural and cognitive differences already, apart from their bilingualism.

Individual difference factors can seriously constrain how someone becomes a bilingual (during the early days of language learning and its later maintenance throughout the lifespan). Bilinguals who have been grouped together to form a homogeneous group to be compared against another are not necessarily homogeneous. Many in the group may have different levels of executive functions that are independent of their bilingualism. The extent to which they are good or bad bilinguals is an effect of their executive control. Their further modulation is of course dependent on continuous practise. This is very easily evident in foreign-language learning courses, where even after many months not all learn to significant levels of success. How does one explain this? If the same bilinguals are examined on different linguistic or non-linguistic tasks, then one will certainly find many differences. To date, very few researchers have looked at how individual difference factors could constrain bilingualism and as a consequence affect our observations on the executive control tasks.

Bilinguals in different countries are also not the same. The practice of bilingualism in different cultures is constrained by local conditions. These constraints directly affect variables such as the quantum of switching and exercise of control. Whether one needs inhibition in a certain bilingual context is dependent on what type of bilingualism is in practice. This logically means that different bilinguals exercise their executive functions (or components of them) differently. If a study with Indian bilinguals finds positive results of advantage and such a study is not replicated in China, then the reasons are probably related to such differences. It is very possible that these different bilinguals may have acquired English as a second language using different components of the executive function system for language control depending on their own environment. When they move to a different culture such as the USA, their executive control settings also change. Contemporary research misses these critical aspects and treats all kinds of bilinguals as if they are similar. Researchers often pool participants with different first languages and histories of bilingualism, which might also be problematic.

The accurate conceptualisation of executive functions, both in neural and behavioural terms, is central to our field. Cognitive psychologists often administer specific tasks to measure apparently unique components of executive functions (a list of tasks appears in Valian, 2015). Most researchers who have studied either form of executive function in bilinguals and have administered familiar tasks such as the Flanker, Stroop, Simon or stop signal tasks use the framework of Miyake et al. (2000). According to Miyake et al. (2000), executive functions are frontal lobe functions that exert top-down control over lower-level functions in the service of goal-directed actions of the organism. These functions include working memory, inhibition, goal maintenance and set shifting. More recently, Miyake and colleagues have suggested that behavioural performance on different tasks that measure these processes often may not correlate well in small samples (Miyake & Friedman, 2012). Further, performance on these tasks is impure because executive functions also have non-executive lower-level processes. Thus, it is difficult to know from
published findings how much of the task performance was a result of core executive function abilities and influenced by bilingualism per se. However, Miyake et al., (2000) suggest that one can arrive at a common mechanism (unity among diversity) that is involved in all the different components of executive control. They also suggest that the executive functions are heritable. One of their other important suggestions is to consider the thesis that top-down control from frontal areas may not be the key mechanism, but that the selection of the correct response through lateral inhibition is more important. Nevertheless, the main point is why don’t bilingualism researchers search for unity in diversity in executive functions in participants who take part in a lot of tasks and where each task apparently gives a score representing a particular executive function? When we administer Stroop and Flanker tasks and only see the bilingual advantage in some, we tend to argue that bilingualism may enhance the mechanism that particular task captures and not the other mechanism. According to Miyake, all of these tasks have in them ‘inhibition’ as a common mechanism, although they also have other attributes. If we adopt this research strategy, then we can seek correlations among tasks to see how bilingualism may modulate the ‘common’ core mechanism that all participants may share.

These days the phrase ‘individual difference’ is heavily used in many fields within the cognitive sciences. It rests on the simple assumption that every person in whom we are measuring any neural or behavioural response is different from the next. This is true given the fact that all of us have different brains and developmental histories. However, experimental psychology attempts to quantify behaviour in a sample of the population who presumably have been taken randomly and are representative of the whole population. It is also assumed that participants within this small sample are homogeneous. Statistical methods are used to measure at what distance the responses of each individual deviates from the mean of the sample. This dispersion or variance offers important information about the sample. However, in reality, most participants differ from one another, often both qualitatively and quantitatively. For example, on a Stroop task, where we assume that most normal participants should be slower on the incongruent trials as these trials pose response-level conflict, we might see that many in a sample do not face any conflict on such trials. Rather, these participants are slower on neutral trials that offer no conflict. Similarly, on the congruent trials where we expect the participants to be faster, many do not manifest this behaviour. What could be the reason for such anomalies? Here lies the role of individual differences. The Stroop task does not capture conflict in everybody. The gross mean values are arrived at after outlier correction or smoothing of the dataset. Importantly, these critical deviations are never discussed in articles, but statistical significance assumes importance. What is important here is to explain why some individuals do not show the classic Stroop effect as one would expect. Will they similarly show no evidence of conflict on incongruent trials on other tasks such the Simon or the Attentional Network Test (ANT)? It may be the case that such individuals show slower responses on incongruent trials on these other tasks but not on the Stroop task. This means that each individual’s neural and cognitive makeup prepares him to encounter a stimulus and act on it in a particular fashion. However, this may not be generalised for a class of tasks that are often grouped together. Following
this rationale, we should not expect all bilinguals in a so-called bilingual sample to be faster or suffer less conflict in a Stroop-like task. On the other hand, in a sample of randomly picked monolinguals, some might show responses typical of bilinguals. Individual difference of this sort can pose serious problems for theoretical predictions. On the other hand, the aim of cognitive psychology is to offer general theories and predictions for most humans. How can one account for individual differences while at the same time expecting a general theoretical prediction to show up?

Individual difference broadly means how one is different from another in his cognitive profile. Friedman and Miyake (2017) suggest that individual difference may account for the variations we see in participants in executive control task performance. This refers to the core cognitive and neural resources anyone brings to a task without additive modulations caused by bilingualism or video game playing. This is something we do not know from the published studies since we always look at the impure data that have different components to it. Basically, I am saying that even if there is some advantage because of the practice of bilingualism, all bilinguals will not show such advantage on tasks. There is a hierarchy among the bilinguals as a group, and this hierarchy is independent of bilingualism and is referred to as individual difference. Unless we have a clear measurement of such factors we will not know the additive effects of bilingualism. Comparing bilinguals with monolinguals is not enough to counter this proposal since many monolinguals may have practised difficult attention demanding skills over a period of time which might have also strengthened some of the other crucial components of their executive functions (Valian, 2015). When such monolinguals are compared with bilinguals, one can expect no group difference. Therefore, baseline scores on individual difference factors are necessary for valid comparisons in this area.

It is also important to examine the methodology of individual differences research and whether it is effective in capturing differences (e.g. between high and low proficient bilinguals). Recently, Hedge, Powell, and Sumner (2017) pointed out the problems with using certain paradigms in correlational research that have been otherwise successful in experimental research. They calculated the test–retest reliability of several classic executive control tasks such as the Stroop, Simon and Flanker tests; low test–retest reliability was observed for most of the tasks. The authors argue that the definition of reliability is different in within-subject experiments and between-subjects/correlational experiments. For instance, the Stroop task is a reliable test to measure executive control because it reproduces the Stroop effect across different laboratories and different samples. Thus, it is a robust test with low between-subject variability. But the very fact that the Stroop effect is so robust also means that it is not a reliable indicator of individual variations in executive control.

This is because, for a measure to be a reliable indicator of group differences it has to be sensitive to such individual differences, which many of the robust executive control tasks are not (hence, their popularity). This leaves us with a paradox where time-tested tasks that are otherwise reliable in capturing a specific cognitive function may not be useful to capture the individual variations in that cognitive function. The solution perhaps is to develop alternate tasks or newer performance measures that are more sensitive to individual variations. For example, Friedman (2016) sug-
gests performing latent variable analysis to capture the executive control-related differences among individuals.

### 8.2.2 Performing Bilingualism and Advantage Research in the real world

Any cognitive or experimental psychologist will acknowledge that laboratory-based tasks have severe limitations. We try to conceptually replicate how humans behave in the real world through these tasks. However, when participants perform these tasks in a laboratory they also entertain constraints that otherwise may not be applicable in real life. How does control operate when bilinguals actually deal with other bilinguals or monolinguals in everyday situations? Do they bring in the kind of control moment by moment as is required, for example, trial after trial in a Stroop task? Unless methodological and technological advancements are made in these directions, we will have no choice but to theorise based on results obtained in laboratory-based tasks. Researchers are now beginning to understand that some closely held assumptions and theoretical conclusions about bilingual psycholinguistic processing may not hold true when one looks at real, everyday language processing. For example, switch cost as is normally found during bilingual mixed object naming is not seen when the task is made more natural (Kleinman & Gollan, 2016). In this section, I discuss the possible areas of advancement that can bring this research area closer to real life, given the new tools available today.

The use of the word ‘context’ in connection with bilingualism is not new. Theoretical proposals by Grosjean on the mode and, more recently, the adaptive control hypothesis have moved the field forward (Green & Abutalebi, 2013; Grosjean, 2001). One can now directly ask when and how and under what circumstances bilinguals bring in control when they are facing an interlocutor. After all, it is the regular exercise of this control over a period of time that boosts the executive control system. A few researchers who have studied this association between interlocutors’ assessment and language planning in bilinguals have used cartoon pictures to which the participants respond (e.g. Bhatia et al., 2017; Molnar et al., 2015). Although these designs lead to the expected results, one could extend this to include more realistic encounters. For example, the use of VR as a research tool to study how bilinguals exercise control as they freely encounter interlocutors in a virtual world would be interesting. This technique allows the simulation of the real-life experiences and can supplement more traditional laboratory-based research. The main advantage of a VR-based design is that it allows an immersive experience for the participants. They feel and react to partners as if they are real. We cannot disregard affective considerations during bilingual language selection in real-life interactions. This is something that is absent in traditional button-press experiments where agents are not embedded into any context. In the VR set-up, agents are more sensitive to sensorimotor and affective cues which can have a strong effect on their current states of cognitive control.
Peeters and Dijkstra (2017) presented pictures to be named in a VR set-up. They wanted to see how language switching works in such a scenario. The results replicated the conventional findings where bilinguals were found to apply higher inhibition to their first language. Although they did not use any realistic images or interlocutors with whom participants could respond to, this study opens the possibility for VR to be used in bilingualism research. Switching data may not be similar when we make the experiment more like real life within the VR, allowing participants to act freely and interact. Eichert, Peeters, and Hagoort (2017) created virtual three-dimensional (3D) objects and studied language-mediated eye movements and prediction with spoken sentences. Language-mediated eye movements are more traditionally studied with two-dimensional (2D) pictures on a computer screen and with an eye tracker. They found that in this set-up participants could predict upcoming words when they encountered the 3D objects. Interestingly, this research also combined eye tracking with VR. This way one can study behaviour in an immersive environment and record online data. I also envisage the use of EEG along with VR to collect neural responses in such a scenario. VR can be used to make more dynamic stimuli that closely mimics real life where participants are allowed to move around and interact, for example to study how context influences the degree of control a bilingual brings in as she dynamically encounters interlocutors of different types. Imagine a classroom scenario and an outdoor scene. In India, English is the lingua franca in an academic set-up. Suppose I want to study whether bilinguals differentially choose languages for the same interlocutors as a function of the environment, then this can be created with VR. Participants will see different interlocutors as they freely move around the VR space of a classroom or a place that represents some other place. It is quite possible that, when asked using newer methods, old questions may produce data that are different than one could predict. Or it is also possible that we see a consistency in the pattern of data in spite of such methods. In any case, we would have made the study and its design more ecologically valid and closer to reality.

Lightweight wearable eye trackers with good sampling rates now allow the tracking of eye movements when participants are engaged in dynamic actions. Many studies are now being performed to understand visual attention during sport or consumer behaviour onsite. This has made studying real-life behaviour and cognition very sophisticated and does not involve the artificiality of the laboratory. So far the data that researchers have generated have used the single-participant model in which he or she undertakes a task on a computer and the experimenter records behaviour using an eye tracker. Using wearable eye trackers on both speaker and hearer and examining how they select language and evaluate any contextual cues could provide key insights. The adaptive control hypothesis emphasises the situational alertness that bilinguals bring during language control.

Using these techniques one can study how adaption actually works during real-life communication. It is also possible to study how different bilinguals process the same stimuli in joint-action tasks. We assume that all bilinguals activate cross-linguistic information in parallel when they process any stimuli. Imagine a visual world task performed by two bilinguals each wearing a head-mounted eye tracker. We can see if their eye movements are similar or different when they process spoken
words and look at visual objects. When we average data, as is the case with traditional analysis, this aspect of individual difference is lost. Similar to eye tracking, researchers can also use wearable EEG recording devices. Suppose we want to understand the neural signatures that change dynamically when two bilinguals are in communication. If we can simultaneously record EEG from both, that data will reveal the manner in which control mechanisms are at work for both. Thus, researchers should use such advanced techniques to answer more difficult questions. These types of equipment will allow the research designs to resemble real-life behaviour more and participants can operate without any constraints. Many excellent articles are available that show how one can use such techniques to study cognition in bilinguals (Tarr & Warren, 2002). Further, these techniques allow us to study special populations that may have a psychological or linguistic disorder that may prevent them from participating freely in a traditional laboratory-based experiment. Such innovation in techniques will allow us to address both old and novel questions, bringing in higher flexibility in design and execution.

8.2.3 The Challenges of Globalisation, Migration and Conflict

Should basic science researchers be worried about the rapid changes in geopolitical order that is underway and its influence on their research? It becomes important when the human being and his cognition is the objective of so many experiments. Psychologists often theorise human cognition in a decontextualised manner where they do not consider the many variables that influence the behaviour of their participants. The study of bilingualism is particularly vulnerable to these forces as data are often collected from immigrants in advanced western countries. Migration, settlement and socio-linguistic variables influence the degree of bilingualism immigrants practice in their host countries. In this book, I discuss cultural influences on the attention system. While cultural neuroscience is now consolidating its theories and research practices, these have yet to be included by bilingualism researchers. In many countries where bilingualism is in practice and is part of official policy, serious language and ethnic conflicts are also seen. How does that shape our research design and interpretations? How are different countries promoting bilingualism of immigrants who do not adjust very well within the constraints of the host country? Cultural and linguistic conflict can influence how such participants react to stimuli in experiments and therefore our theories about them. Here I briefly indicate the issues that should be addressed while we still remain focused narrowly on the question of bilingualism and its influence on cognition.

It is fair to assume that in most advanced western countries, the hosts are monolinguals and the immigrants are either bilinguals or multilingual. This is not to say that a small percentage of the hosts do not learn the other’s language as a second language at school. Different countries have allowed the immigrants to assimilate into their linguistic-cultural context to different levels. A case in point is the migration of nationals of former Dutch colonies into the Netherlands in the last few
decades (Extra & Verhoeven, 1999) or migration of Turkish nationals into Germany. First-generation immigrants need to study the host language and become competent to join the workforce. However, in reality they often use their native language among themselves and stay in areas where it is the only language of everyday communication, meaning they do not become bilinguals as one would expect. On the other hand, the native majority monolinguals do not learn the immigrant’s language for a number of reasons. This situation exists today in many European countries. Therefore, when researchers pick bilinguals as their participants and administer linguistic or cognitive tasks, they overlook their migrational histories. If only highly educated university students are taken as bilinguals, then such results cannot be generalised to large populations. Many countries have promoted bilingualism both in the host and immigrant populations as they view it to be economically and culturally beneficial. Immigrant bilinguals have been shown to be more ambitious in social integration and also show an advantage in cognitive tasks in some situations (Medvedeva & Portes, 2017). Recent studies with Polish migrant children in the UK have shown how exposure to second language (L2) could negatively influence their language skills in native language (L1) compared to non-migrant monolingual children (Haman et al., 2017). In other locations where bilingualism is cherished, one also sees linguistic conflict in everyday life and politics, such as in Belgium (Janssens, 2015). Many other examples can be provided from other bilingual places where bilingualism is in practice along with linguistic conflict.

At a practical level, when we are asking questions about bilingualism-driven cognitive and executive control, it is important to ask what types of bilinguals we are talking about. Are we talking about third-generation immigrants who have well-integrated into the host’s culture or those who are struggling to adapt and are also losing their first language as a result of conflict and lack of multilingual education? The kinds of cognitive adjustments these two types of bilinguals make every day are very different, and when examined on tasks their results will vary. Most researchers study university students who speak English well and not other minority and marginalised populations who are also bilinguals but do not possess good fluency. When data are compared cross-culturally, these variables are not discussed in the interpretation of the data. I do not think that the bilingual cognitive advantage question can be holistically answered in a culture-neutral way. No one wants to say the immigrants are cognitively superior because they speak two languages in these changing times, and particularly where immigration is a political issue. I focus more on immigration since that is a huge source of bilingualism compared with host majorities learning a new language.

The few studies conducted on the nature of bilingualism, immigrant status and control suggest that these questions have no clear answers as of yet. The concept of cognitive reserve has been linked to the practice of bilingualism. Bilingualism is believed to lead to later onset of dementia as it boosts cognitive reserve. Is this true for immigrant populations? Of course, in other chapters, I have critiqued the hospital-based studies that tracked patients’ bilingual histories post hoc and found that the onset age of disease was later than monolinguals. The few studies from India (Alladi et al., 2013) could also be misleading on this front as they were confounded
by factors such as multilingualism and illiteracy (factors unique to India). Nevertheless, there have been some longitudinal studies with richer experimental methods that have tracked healthy older bilinguals until some of them developed dementia. Zahodne, Schofield, Farrell, Stern, and Manly (2014) studied a large cohort of Spanish-speaking Hispanic immigrants in Manhattan (New York, USA) who were tracked for 23 years. Over the period 282 older adults developed dementia. The authors found that at baseline, bilinguals had superior working memory and executive functions compared with monolinguals. However, bilingualism did not predict the onset age of dementia. This means that bilingualism did not particularly delay the onset of dementia.

The immigration question is more important to Europe, the USA and Canada than in India, China or Japan. It may also be important to Australia. It is certainly important to language conflict zones such as the Basque country and Belgium. In practical terms, it comes down to whether these immigrants are used as participants and compared against local monolinguals and are shown to have a cognitive advantage. Many researchers also have a confounding opinion about the role of the socio-economic status of the participants. The socio-economic status of immigrants is often lower than the majority host in many countries. If data collection is restricted to university students, then this variable may not be that critical and one can assume some amount of homogeneity. However, if all kinds of bilinguals are to be randomly included then their socio-economic status will decide their literacy attainment and thus cognitive and intellectual achievement. Of course, some studies show that bilingualism independently modulates executive functioning in low socio-economic immigrant children (Thomas-Sunesson, Hakuta, & Bialystok, 2018).

This chapter is focused on what we can possibly do to make our research designs more holistic, keeping in mind real-life problems that influence bilingualism and in turn executive control. More longitudinal studies should be undertaken on immigrants that arrive in advanced European and other western countries to track changes in executive control. Studies should be undertaken with Indian illiterates who are also bilinguals. Research conducted by me and my colleagues have shown that illiterates show poor cognitive functioning in visual and attentional domains compared with literates (e.g. Olivers, Huettig, Singh, & Mishra, 2014). Further, we have also shown that the adult illiterate brain is plastic and rewires itself with a mere few months of literacy training (Skeide et al., 2017). Illiteracy is still a social problem in many countries, including China, Latin America countries and also Africa. We can no longer base all our theories on university students. In India, many illiterate people learn to speak more than one language. Could they have better executive control than monolingual literates? We do not know the answer to this question as it has not been explored. Studies should track how they develop as bilinguals and why a majority do not master the second language. In addition, studies should also examine how monolinguals from the host countries change as a result of this mixing of cultures and become bilinguals. Cross-sectional studies do not tell us how learning a second language during adulthood modulates executive control. There should also be more cross-cultural comparative studies to see why advantage is found in a certain population but is absent in another similar population. While I have mostly observed execu-
tive control advantage in Indian bilinguals who are highly proficient in the second language, we could not replicate this effect in a sample of French–English bilinguals in Canada (Saint-Aubin et al., in press). At best, one could point to cultural differences and socio-linguistic aspects of bilingualism in both places as the cause for non-replication. The tremendous influence of context on the bilingual’s control system cannot be disregarded. Chinese–English bilinguals do not face the same challenges and demands in their control settings when they are in Beijing as when they are tested in New York City. Adjusting to an L1-dominant culture has different demands on executive control than living in an L2-dominant culture. It is also important to study what happens to the executive control system when bilinguals shift from one language environment to another. These questions will reveal the dynamic nature of bilingualism and how it sculpts neural and behavioural mechanisms.

8.2.4 Finding a Coherent Framework

In her review titled “The Bilingual Adaptation: How Minds Accommodate Experience” (Bialystok 2017) suggested that most diverge findings that either arise from conceptual or methodological differences can be explained if we focus on one unifying cognitive variable. She suggested that this variable could be “executive attention”. There are reasons to believe that ‘attention’ indeed could be the variable that has the potential to reveal how the human mind focuses on task-oriented goals and avoids distracters. Conceptual frameworks such as ‘inhibitory control’ or ‘monitoring’ can be explained using attention as a system. It is easy to accept that bilinguals focus attention on one language when they are trying to speak in that language and not on the other language, albeit recent studies have shown that they can keep both representations active and flexibly manipulate them as desired (Chung-Fat-Yim et al., 2017). In addition, they can disengage attention faster from a stimulus and move it around (Mishra et al., 2012). Beyond explaining performances on tasks such as Stroop, Simon, ANT or the visual search task, which invariably use attentional resources, studying attention deeply also has other important benefits. It is overwhelmingly acknowledged now that attention is the key to understanding our conscious experiences. Attention can help us operationalise consciousness and also many other higher-order subjective aspects such as emotion and awareness (Hedger, Adams, & Garner, 2015; Pessoa, 2005). Much recent work links our sense of agenthood to attentional processing (Hon, 2017). Attention is also one of the most heavily researched and developed topics in cognitive psychology. Using one unified conceptual framework could also help us understand the individual differences and divergent patterns of results better. Attention is involved in both inhibitory control as well as task switching (e.g. Rubinstein, Meyer, & Evans, 2001). The field cannot sustain itself if every researcher administers a bunch of tasks and finds significant differences between bilinguals and monolinguals on some and not on others and then starts theorising that bilingualism may boost those very cognitive abilities that those tasks utilise. This approach does not lead to any holistic theorising, only producing more unexplainable data in the long run.
8.2.5 New Frontiers: Beyond Executive Control

Let us assume that bilinguals or multilinguals have superior executive control, at least in some of the components, compared with monolinguals. Let us also assume that lifelong practice confers a cognitive reserve that significantly delays dreaded diseases. Even if this is so, what is its use in the real world? Are bilinguals better negotiators and resolvers of everyday conflict than monolinguals? Do bilingual children bully less than monolingual children at schools and have better control over emotional impulses? These real-world problems need to be explicitly studied now beyond bilingualism. Do bilinguals appreciate others’ cultures more and show more altruistic tendencies than monolinguals? A few studies have looked at creativity and found that bilinguals are more creative than monolinguals. Do bilingual older adults show more productivity than their monolingual peers if they have more executive control?

I am basically asking whether bilinguals (balanced with years of practice of bilingualism) can transfer their superior executive control to solve real-world individual or societal problems? Let us use the example of the many studies in meditators. Meditators with many years of practice show superior attentional states and emotion control, including focused attention in the face of distraction (Engen, Bernhardt, Skottnik, Ricard, & Singer, 2017). Experienced meditators can quickly get into a mode of ‘attentional flow’ that allows them to stay focused for a longer time. The famous Tibetan Buddhist monk the Dalai Lama preaches that peace is achievable through meditation, which can bestow important qualities such as compassion. I am comparing meditation to bilingualism since both seem to influence, modulate and restructure frontal lobe functions. Just as fMRI studies in bilinguals have shown the special functioning of the ACC in the face of conflict, studies in meditators have also shown similar results (Tang et al., 2009). This means these skills influence the brain and the attentional processes similarly. Or is the effect of language control restricted to only a few domains and not to higher-order scenarios? Does bilingualism lead to its practitioners experiencing ‘attentional flow’ and effortlessness in task execution? More longitudinal studies should be conducted to determine the neural and behavioural changes associated with bilingualism and its influence on real-world conflict management. Many studies performed on experienced musicians and sportspersons show such changes in the neural structures supporting executive control and attention (Babiloni et al., 2010; Gaser & Schlau, 2003). Of course, experienced sportspersons display much aggression during their play even with such control. It is important to compare studies like these and see whether bilingualism, and not sport or music learning, particularly influences certain pathways of emotion regulation. This will lead to the promotion of bilingualism with a clear notion of its use in real-world scenarios.

What use is executive control in a population of bilinguals if they cannot use it to sort out social and ethnic conflicts? In India, where most people are bilingual, we see ethnic conflict in many areas. Bilingualism does not seem to help people negotiate and reconcile things when it comes to violence. However, some studies are beginning to indicate that bilingualism may influence emotion regulation network in children. For example, Ren, Wyver, Xu Rattanasone, and Demuth (2016) report
that bilingualism is related to emotion regulation and social skills in Mandarin–English children. This sort of research has real-world use considering the many children who arrive in western countries at a young age and will become bilinguals after acquiring the host’s language. Will they be better able to manage the emotion and conflict they face than the monolinguals? Of course, as of yet, no longitudinal study has been undertaken on this issue, which shows it to be a new area of research. Some studies have shown that bilinguals are better able to regulate emotions in their second language (Morawetz, Oganian, Schlickeiser, Jacobs, & Heekeren, 2017); however, the role of executive control in this mechanism is not yet clear. One can also compare how bilingual and monolingual children who find themselves in conflict zones adjust to traumatic stress (Diab, Peltonen, Qouta, Palosaari, & Punamäki, 2017). Does bilingualism help one to adjust better to societal conflicts?

Linguistic identities have been the source of many continuing social and ethnic conflicts around the world. The growing nationalistic tendencies in many parts of the world do not accommodate multilingualism. Sociolinguists have long studied the relationship between language identity, power and social solidarity. In an interesting analysis of language policy after the collapse of the former Soviet Union and the many smaller countries that rose out of it, Duncan and Mavisakalyan (2015) suggest that balanced bilingualism has been shown to be a conflict resolver. When different language-speaking people are integrated together and develop a healthy and balanced bilingualism, occurrences of conflict also drops. Could this be because of overall growth in collective executive control in such people? Let us consider the case of Arab–Israeli conflicts. There are research reports that show progressive bilingual Palestinian–Arabic and Jewish bilingual education at school could promote peace in the long-term (Arar & Massry-Herzalah, 2017). As such, there are now many inclusive and multilingual schools in Israel that are perceived as an important element in achieving long-term peace (Bekerman, 2016). It has also been suggested that when language policies promote bilingualism at school, it also serves as an important vehicle for other societal negotiations in conflict zones (Amara, 2017). One cannot rule out this possibility, although socio-linguists do not empirically measure such variables but instead depend on ethnographic and qualitative data to make assertions. Nevertheless, if growing bilingualism leads to lesser conflicts in well-known warring groups that have fought historically, I see a role of cognitive and executive control. Therefore, such studies have to be conducted with an interdisciplinary approach including cognitive psychology, psycholinguistics and sociolinguistics, and culture studies.

8.3 Summary

With everyday advancement in experimental methods and our growing understanding of the human brain, it is now possible to expand the research domains that study bilingualism. Of course, close scrutiny of positive findings that come out of smaller sample sizes and do not replicate well is necessary, but this is an issue in most of the
psychological sciences. The future of the bilingual advantage question lies in more in-depth work on its neural and behavioural aspects in diversified populations. Findings from a few bilinguals from selected spots won’t be sufficient and satisfactory in the development of a holistic theory. Bilingualism and bilinguals differ from country to country with respect to their styles of acquisition, switching, communication patterns, and so on. These variables need to be incorporated into experimental designs in order for us to understand how cultural forces shape the neural machinery that supports bilingualism. In Chap. 1, I emphasised the fact that the evolution of bilingualism in our species also indicates the unique evolution of social cognition. To learn and use two languages is to be accommodative and socially more communicative. This aspect of bilingualism should be our focus as it can explain how humans cooperate with one another despite enormous differences in their cultural outlook and belief systems. Numerous gaps in our understanding exist with regards to how bilinguals exercise control for linguistic and non-linguistic stimuli. Although some researchers have attempted to understand this through correlations on various tasks, a clear mechanistic explanation remains to be offered. The study of control that bilinguals exercise in the different real-life communicative scenarios is enormously important, as is the question of interlocutors’ influence and how bilinguals adjust dynamically. The adaptive control hypothesis is a good step forward that considers these contextual factors in explaining neural control. Finally, the baby should not be thrown out with the bathwater—the advantage question is still very important as it shows sculpting of the human brain through language use. Answering this question has deep evolutionary significance for us.

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