Effects of bilingualism on cognitive-linguistic abilities

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Declaration

I certify that the research presented in the thesis is my original work conducted as part of my PhD research under the supervision of Prof Lyndsey Nickels and Dr Britta Biedermann. No parts of this research work has been submitted towards the award of any other higher research degree to another institution or university. Ethics approval for this PhD project was obtained from the Human Research Ethics Committee, Macquarie University (Reference No. 5201100891).

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I hope that this little piece of research will contribute to the growing body of research on bilingualism. Through this thesis, I would like to acknowledge the role of indigenous communities of the world for sustaining, nurturing and promoting bilingualism since centuries.

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General Summary

This thesis examines the effects of bilingualism on three key areas of cognition and language - cognitive control, sentence recognition and word learning. The first study investigated the effect of socio-economic status on bilingual cognitive control. Previous studies have suggested that the advantages shown by bilinguals on some cognitive tasks may be associated with higher socio-economic status. We therefore explored this issue in bilingual and monolingual illiterates of lower socio-economic status. We administered two cognitive control tasks: The Simon task and the Attentional Network task. The results showed that bilinguals were faster overall than monolinguals for both tasks: a global bilingual advantage. The finding of a bilingual advantage even for individuals of comparable lower socio-economic status confirms that these advantages are not due to a confound with higher socio-economic status.

In the second study, we examined the effect of bilingualism in linguistic domain. More specifically, we explored whether bilingualism is associated with a sentence recognition cost in even in the native language. We tested sentence recognition abilities in bilinguals and monolinguals in the presence of a non-linguistic distractor (background noise). Our results indicated similar sentence recognition accuracy for bilinguals and monolinguals when the sentences were presented in quiet conditions and even when presented in noise.

The final two studies in the thesis examined whether the positive effects of bilingualism extend to benefit language learning. We investigated language learning using a novel word learning task. In the third study, novel word learning abilities in late bilinguals were compared with early bilinguals and monolinguals to see if a delayed onset age of second language acquisition also results in a bilingual advantage. Although we found an overall advantage for early bilinguals, critically, we also found a learning advantage for late bilinguals compared to monolinguals. This suggests that although age of acquisition of a

second language has an impact on word learning abilities, second language acquisition also seems to modulate the late bilinguals' ability for word learning.

In the final study, we examined the specific mechanisms that drive the advantages of bilingual speakers for novel word learning. We specifically manipulated the phonotactic probability and phonological neighbourhood density of the novel words to see if bilingual advantages are influenced by these properties. We found a bilingual advantage for learning novel words regardless of phonotactic probability and neighbourhood density effects indicating that the mechanisms underlying bilingual word learning advantages are not constrained by the phonological and lexical features of the novel words.

The evidence from all four studies is summarised in the final chapter and current models of bilingualism are used to inform our understanding of the patterns observed. Finally, this thesis highlights that the positive consequences of bilingualism are not confined to cognitive control mechanisms, and bilingualism exerts unique effects in other domains such as novel word learning.

Chapter 1:

Introduction

From the most ancient hunter gatherers to the modern day, learning and speaking a language other than the native tongue can be considered to be a societal norm. In fact bilingualism (and by extension multilingualism) has been described as one of the primary human conditions (Vaid & Meuter, 2013): Our ancestors were mostly multilingual (for example, the indigenous communities of Papua New Guinea; Evans, 2011). Given this rich history and significance for society it is not surprising that, in modern times, bilingualism has evolved from a social phenomenon to an independent field of research. More specifically, in the last decade, research on bilingualism has become a focus of both psycholinguistic and neurolinguistic research. This growing interest in bilingualism has been motivated by the understanding that the relationship between human cognitive and linguistic systems can be best understood by studying bilinguals rather than monolinguals alone (e.g., Kroll, Dussias, Bogulski, &Valdes Kroff, 2012). The critical motivator for this research is the evidence that experience with multiple languages may have cognitive and linguistic consequences, both positive and negative (e.g., Abutalebi, Canini, Della Rosa, Green, & Weekes, 2015; Abutalebi & Green, 2007; Bialystok, Craik, Klein, & Viswanathan, 2004; Costa, Hernandez, & Sebastián-Gallés, 2008; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Kaushanskaya & Marian, 2009b; Prior & Gollan, 2011).

The positive effects of bilingualism have been known for some time, including, for example, the landmark study by Peal and Lambert in the1960’s showing that bilingual children performed better than monolingual children on tasks measuring verbal and nonverbal intelligence. However, more recently studies have demonstrated a bilingual advantage specifically for cognitive-linguistic tasks measuring conflict resolution and monitoring and language (word) learning (e.g., Abutalebi et al., 2011; Bartolotti, Marian, Schroeder, & Shook, 2011; Bialystok, Craik, & Ryan, 2006). However, not all effects associated with bilingualism are positive especially for linguistic processing tasks measured through lexical access (e.g., picture naming: Gollan et al., 2005).

Nevertheless, many questions remain unanswered as to how different bilingual experiences (e.g., early vs. late bilingual status) and environmental variables (e.g., socio economic status) influence bilingual advantages in these domains. The central aim of this thesis is to explore the effects of bilingualism in relation to these issues on three key areas of cognition and language – *cognitive control, sentence recognition* and *word learning*. This introductory chapter reviews cognitive models of bilingual language production in order to provide a context to the debates in the thesis. The chapter concludes with an orientation to the structure of the remainder of this thesis.

Cognitive Models of Bilingual Language Processing

Early research on bilingual language production was directed towards whether lexical processing in bilinguals is based on an independent or shared language system. Evidence came from two sources – psycholinguistic language processing studies and neurolinguistic studies on bilingual people with aphasia. For instance, Gerard and Scarborough (1989) argued that bilingual language function is guided by independent lexical systems and both languages are accessed separately during word recognition (i.e., only the one that is needed during word recognition is accessed). In addition, evidence from bilingual aphasia showed differential recovery of languages suggesting a dissociation between language processing as well the autonomy of a bilingual's languages (see, for example, Albert & Obler (1978) and Paradis (1997) for a detail). This early research has led to the development of a number of theories of bilingual language processing and control. We will now outline major theories in the field.

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

The independence of a bilingual's language systems at the lexical level was also the focus of some of the earliest psycholinguistic models. For example, Kroll & Stewart (1994) claimed in the Revised Hierarchical Model, that language (word) processing in bilinguals is mediated by separate lexicons but with a shared conceptual system (see Figure 1).

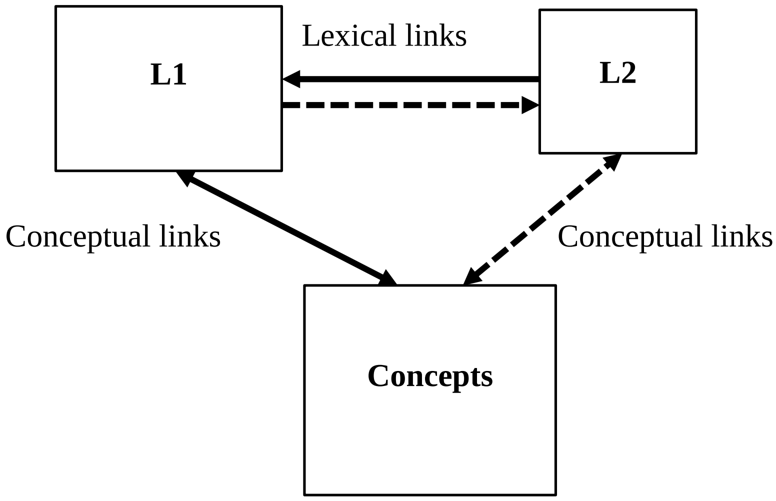

Figure 1. Revised Hierarchical Model for lexical and conceptual representation of bilingual memory (Redrawn from Kroll & Stewart, 1994).

Although this model was developed for word production and was based on translation tasks, for over a decade, the RHM was the dominant model of bilingual word processing. One of the central assumptions of this model is that bilinguals possess a larger vocabulary in their native language (L1), even if the proficiency of L1 and their second language (L2) is comparable. Kroll & Stewart (1994) argued that since bilinguals translate from L2 to L1 faster than from L1 to L2 the lexical association between L2-L1 is much stronger. Kroll & Stewart (1994) also propose that the relative connection strength between the L1 lexicon and the L2 lexicon varies depending on the fluency in (proficiency of) L2 as well as the dominance of L1 over L2. However, the strong associative link from L2 to L1 is maintained only at the lexical level. At the conceptual level, L1 exerts a stronger connection with concepts because of the earlier, and therefore more established experience with the language -

although a weak association is also evident for L2. Kroll and Stewart (1994) propose that for bilinguals with a delayed onset of second language acquisition (e.g., after 12 years), initial vocabulary acquisition in their L2 is mediated through translation routes from L1. That is, the lexical link from L2 to conceptual memory is established through lexical translations in L1. However, as proficiency increases, direct links are developed from the L2 lexical system to conceptual memory, although the translation links from L2 to L1 still remain. The connection strength from the L1 lexicon to conceptual memory remains robust and unchanged.

Evidence against independent language selection

Critics argue that one of the major challenges for RHM is its inability to account for the joint activation of both languages in bilinguals (in contrast to selective access to separate lexicons for each language; see Brysbaert & Duyck, 2010 for a detailed review). Evidence from a range of modalities including visual word recognition (e.g.,Van Heuven, Dijkstra, & Grainger, 1998), spoken language processing (e.g., Marian & Spivey, 2003; Marian, Blumenfeld, & Boukrina, 2008; Shook & Marian, 2011; Spivey & Marian, 1999) and evidence from parallel recovery in bilingual aphasia (e.g., Fabbro, 2001; Marangolo, Rizzi, Peran, Piras, & Sabatini, 2009) suggested parallel activation of both languages during bilingual language processing. For example, Marian and Spivey (2003) conducted two experiments to examine lexical competition within and between languages in Russian (L1)-English (L2) bilinguals. Participants were asked to pick up a target object from a set of within and between language competitors. Within language competitors were object names that were phonologically related to the target in the target language (L1 or L2) (e.g. related in English for an English target: target object ‘plug’ and English competitor ‘plum’). Between language competitors were object names in the non-target language that were phonologically related to the of the target word (e.g. a Russian word phonologically related to the English target: target object ‘plug’ Russian competitor ‘plat’e (dress)’). The participants were tested in both English and Russian and eye movements were simultaneously recorded. The proportion of the eye movements to the distractors revealed that participants experienced competition from both within language and between languages. However, between language competition was only significant when tested in English (L2) and not in Russian (although there was a non-significant trend in the same direction). Nonetheless, these findings replicated earlier evidence for parallel activation contradicting the assumption of independent lexicons and language specific lexical access (Spivey & Marian, 1999).

While it is now generally accepted that there is strong evidence for parallel activation of languages, Kroll, van Hell, Tokowicz and Green (2010) argued that this is not contrary to the central assumption of RHM, including the existence of separate lexicons. Kroll et al suggest that a functional separation exists at the level of lexical representation while parallel activation of these lexicons may well be the likely scenario during lexical access.

The Bilingual Interactive Activation Model (BIA)

Despite strong initial support in favour of the RHM (for discussion see Kroll, van Hell, Tokowicz, & Green, 2010), Van Heuven, Dijkstra, & Grainger, 1998) proposed a model with integrated lexicons (see Figure 2) for visual word recognition.

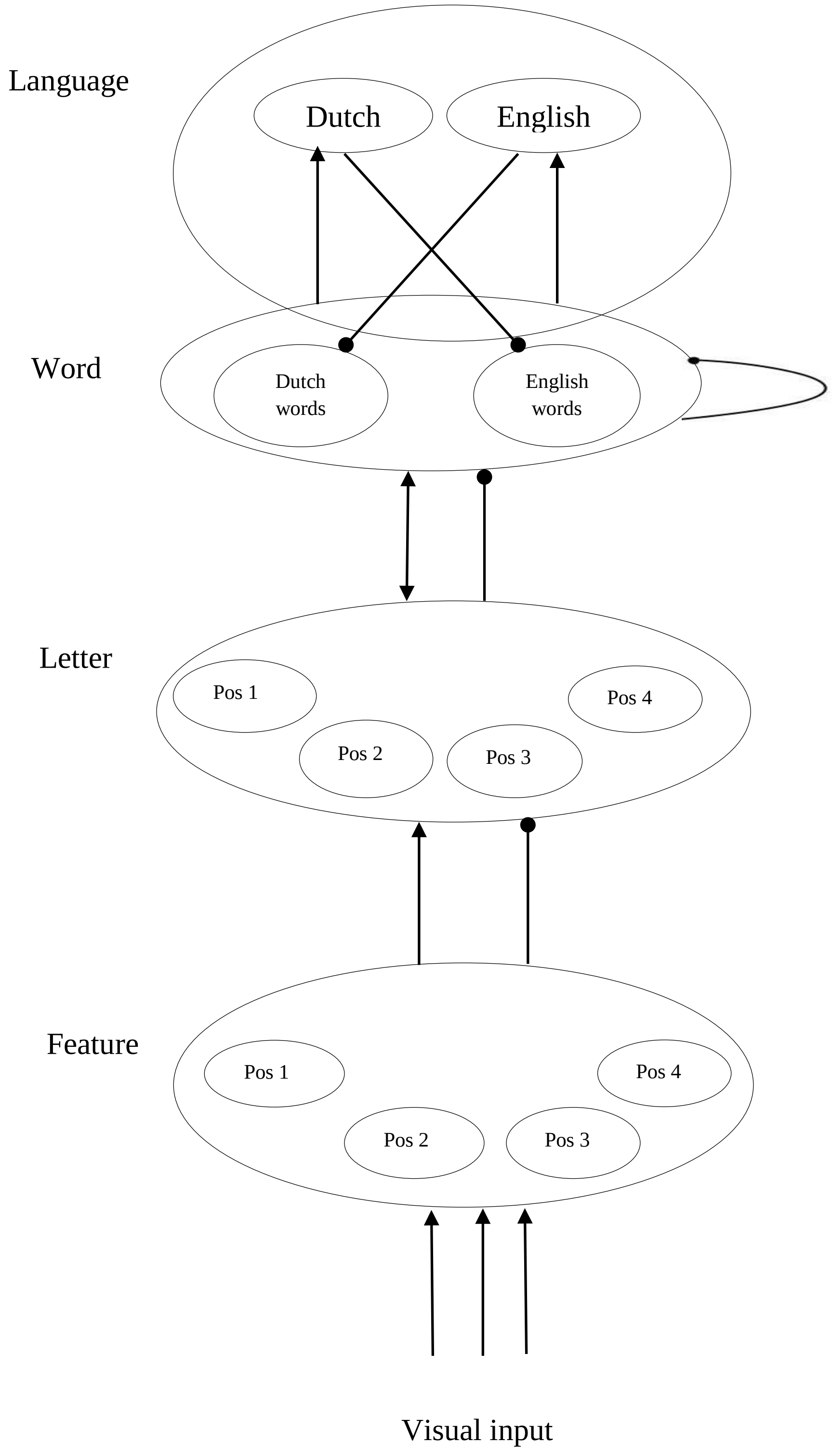

Figure 2. The Bilingual Interactive Activation Model (Redrawn from Van Heuven, Dijkstra, & Grainger, 1998). Arrow heads indicate excitatory connections and bolded circles indicate inhibitory connections.

Van Heuven, Dijkstra and Grainger (1998) developed a computational model, the Bilingual Interactive Activation (BIA) model to account for their experimental results on language selective access (lexical access of only the target language) and non-selective access (parallel activation of all known languages regardless of the target language) in bilinguals. For example, Van Heuven, Dijkstra and Grainger (1998) conducted a number of experiments on Dutch-English bilinguals and English monolinguals manipulating orthographic neighbourhood density, which is known to affect speed of lexical decision (higher neighbourhood density words are responded to slower). They predicted that if bilingual word recognition was mediated by language selective lexical access, the recognition of words in a target language (Dutch) would only be influenced by orthographic neighbourhood manipulations in that language. In contrast, if bilingual word recognition involves non-selective lexical access where visual input activates both languages, recognition of words in the target language (Dutch) would be influenced by manipulating orthographic neighbourhood density in either language (Dutch or English). This prediction arises because in non-selective lexical access a Dutch word will activate all words in the lexicon that share letters, irrespective of whether these words are Dutch or English. Their results supported non-selective lexical access: the response time for (visual) word recognition was slower for L2 (English) words when these words had many Dutch (L1) orthographic neighbours, and word recognition in Dutch was slower when the target word had many English (L2) orthographic neighbours. Van Heuven, Dijkstra and Grainger (1998) developed the BIA model to account for this evidence of language non-selective access during visual word recognition.

The BIA model was originally developed taking inspiration from the monolingual Interactive Activation model of Reading (McClelland & Rumelhart, 1981). BIA further extended this model to incorporate additional Dutch lexicons and a shared Dutch-English lexicon. One of the key features of this model is the language non-selective bottom up processing and language selective top down processing. It was proposed that upon seeing the visual input bilinguals activate all letters that correspond to the features of the visual input. Activation of letters that do not coincide with the input features is inhibited at this level. In the next phase, activated letters excite words in both languages that comprise these letters and these words, in turn, send feedback to the letters. Inhibition is a key element at this level with activated words inhibiting all other words in the lexicon. Subsequently, activation from the word level is passed on to the language node: words that correspond to each language will excite their specific language node. Moreover, excitation of one language node leads to the inhibition of the other language node(s). For example, activation of words in Dutch will result in the inhibition of words in English. Note that the specific language selection mechanism only operates via the language nodes inhibiting words in the non-target language. Van Heuven, Dijkstra and Grainger (1998) have argued that a parallel can be drawn between inhibitory mechanisms in the BIA model and other bilingual models (e.g., Green, 1986) that consider inhibition a key element in bilingual language processing.

The Bilingual Interactive Activation Plus (BIA+) model

Although the BIA model was successful in simulating non-selective language access in word recognition, the model did not specify the phonological and semantic representation of these word forms. Consequently, the model was unable to account for some phenomena, including, for example, between language phonological priming effects (Brysbaert & Dijkstra, 2006). Consequently, Dijkstra and Van Heuven (2002) extended BIA enabling it to simulate more tasks and terming it the Bilingual Interactive Activation plus (BIA+) model (see Figure 3).

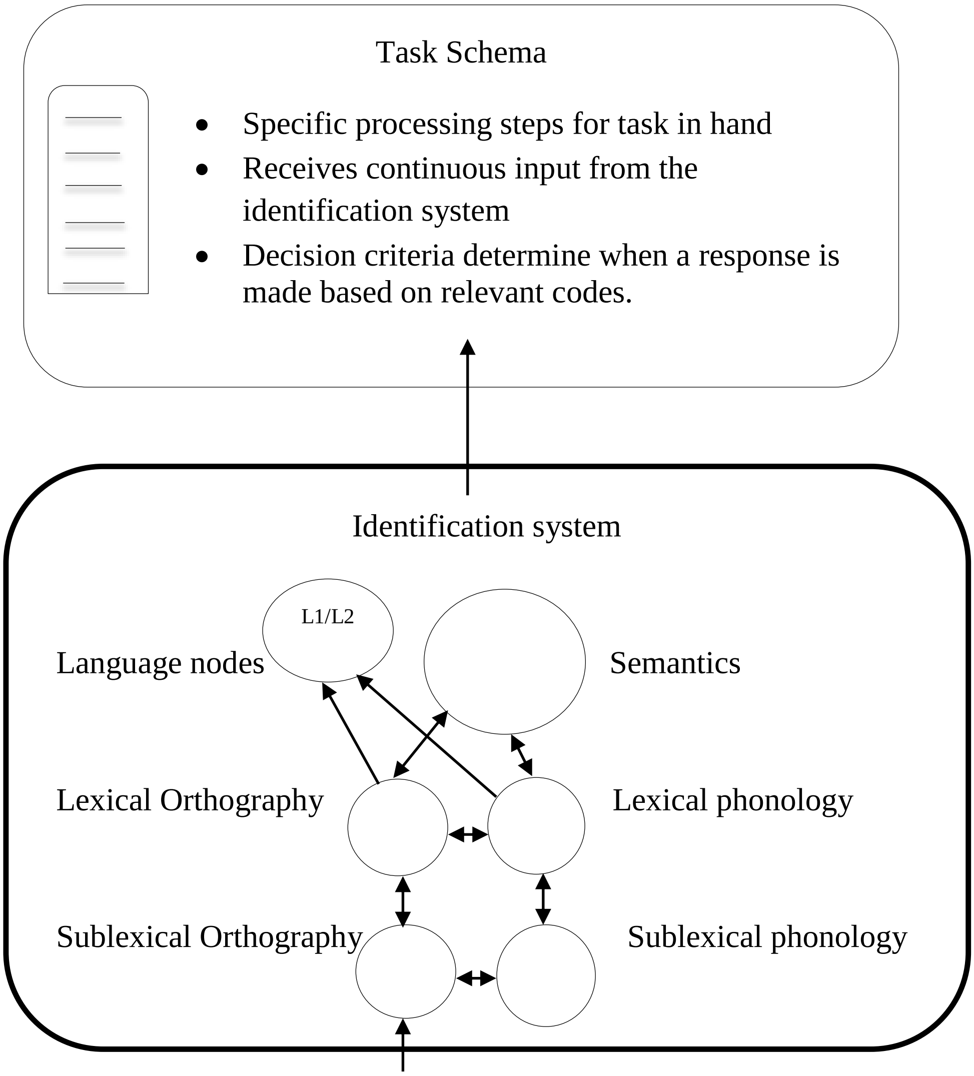

Figure 3. The Bilingual Interactive Activation Plus model (BIA+) (Redrawn from Dijkstra & Van Heuven, 2002).

The BIA+ model includes a separate word identification and task schema system. At the level of the word identification system, in contrast to BIA, BIA+ has no feedback to the word forms from the language nodes. The BIA+ model includes both phonology and semantics and therefore the word recognition system is influenced not only by orthographic but by semantic and phonological features.

Within BIA+ the task schema controls skills that require inhibitory abilities. This component involves processes required for overseeing different task demands. For example, it includes attentional mechanisms that may be needed for tasks such as lexical decision

(Brysbaert & Dijkstra, 2006). Dijkstra and Van Heuven (2002) suggested that the task schema was similar to the inhibitory mechanism proposed in the Inhibitory Control model (Green, 1998). While the Inhibitory Control model proposes an influence of non-linguistic mechanisms at the level of language production, the task schema for BIA+ manages these mechanisms at the level of the lexico-semantic and word recognition systems (Dijkstra & Van Heuven, 2002).

Although BIA+ continues to explain language non-selective access and has extended BIA to include phonological and semantic effects, it still has many limitations. The first challenge is to develop BIA+ as a fully-fledged computational model. Second, there is the fact that there can be non-parallel recovery across languages in bilingual aphasia (e.g., Fabbro, 2001; Marangolo et al. 2009). It is unclear how BIA+ could account for such differential recovery patterns (Brysbaert & Dijkstra, 2006). Finally, both BIA and BIA+ are developed based on visual word recognition tasks. Without expansion, BIA+ cannot therefore account for results from the domain of auditory word recognition and spoken word production (for similar concerns see also Kroll, van Hell, Tokowicz, & Green, 2010).

The Bilingual Language Interaction Network for Comprehension of Speech (BLINCS)

Recently, Shook and Marian (2012) developed "The Bilingual Language Interaction Network for Comprehension of Speech (BLINCS)", a computational model that may account for cross-linguistic interaction during language processing. BLINCS encompasses language representations at multiple levels - phonological, phono-lexical, ortho-lexical and semantic, which are connected by bidirectional interactive links. One of the core features of this model is the inter-connected self-organizing maps (SOMs), The SOMs are capable of detecting the incoming information and mapping it onto the node that best matches with the input through unsupervised learning algorithms. The value of the selected node is changed so that it becomes more similar to the input, as are surrounding nodes (to a lesser degree) resulting in similar inputs mapping onto nodes that are close together in the model's space.

Both language-shared and language-specific representations are organised within a single level. Communication and competition between languages occurs due to the lateral links between translation-equivalents and the activation of items that are close in the maps (which are both activated together and also inhibit each other). The model assumes that there is a selective individual item to item inhibition of words from the non-target language to improve the selective language activation of the target language. However, although Shook and Marian do not suggest it, it is likely that instead of an item to item inhibition a language selection could be also achieved through the activation of a general inhibitory control mechanism. However, given that it is designed to simulate language comprehension, it is beyond the scope of the model to make specific predictions regarding language selection in bilingual language production.

The Inhibitory Control Model (Green, 1998)

In the domain of language production, Green (1998) developed an influential model for bilingual language selection based on inhibitory mechanisms (see Figure 4).

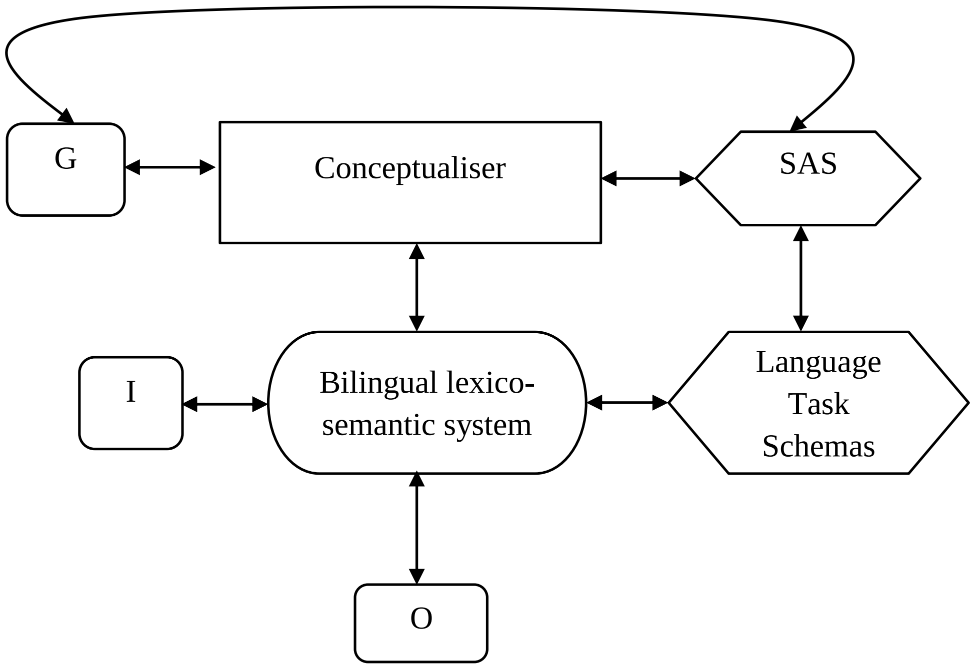

Figure 4. The Bilingual Inhibitory Control model for language production. Redrawn from Green (1998) (G = Goal, I = Input, O = Output).

The Inhibitory Control model incorporates three core features for language production and control – (i) the lexico-semantic system, (ii) language task schema and (iii) the supervisory attentional system (SAS). The lexico-semantic system, which is crucial to language processing, receives information from the conceptualiser. On the other hand, syntactic properties, such as word category, grammatical gender, or grammatical number are captured in so-called lemmas[1] (see Levelt, Roelofs, & Meyer, 1999). Lemmas are linked to the conceptualiser and contain language specific tags. The language specific tags (L1 or L2) are required for specific language selection. The activation of L1 lexical concepts not only activates corresponding lemmas in L1 but also activates L2 lemmas. Therefore a language task schema assists in selecting the target lemma by inhibiting the activation of non-target lemmas. Note that the language task schema inhibits both within language and between

[1] *A lemma is a term that is generally used to denote a level of representation corresponding to the lexical-semantic and syntactic properties of a given word (originally introduced by Kempen & Huijbers, 1983). Later, Levelt et al. (1999) modified the scope of the term slightly to refer only to purely syntactic information.*

language non-target lemmas in relation to the task demands (e.g., production or translation schema).

Green (1998) makes a clear distinction between a schema and long-term memory. For example, he suggests that the language task schema is not simply a long-term memory trace but is specialised for adaptive or constructive functions that individuals may implement for task completion. If the task has been previously performed, then the relevant schema can be retrieved from memory and implemented successfully. However when the individual performs a novel skill, a specialised monitoring and controlling system known as the Supervisory Attentional System (SAS) takes over this task to facilitate its successful completion. Therefore the SAS plays an important role in commanding, modifying and monitoring the performance of a variety of tasks (Green, 1998). The SAS plays a critical role during language production in overseeing the inhibition of non-target lemmas and in facilitating the selection of language and task appropriate schemas. Such ideas of monitoring systems can be found in earlier models, including computational models explaining high level control of daily actions (e.g., Cooper & Shallice, 1997) and language production in bilinguals (e.g., Albert & Obler, 1978).

Although the Inhibitory Control model is able to explain language selection and inhibition, more recently, Green and Abutalebi (2013) proposed the Adaptive Control Hypothesis, a broader account involving eight specialised cognitive skills employed depending on the language context (see below).

The Adaptive Control Hypothesis

Green and Abutalebi (2013) proposed eight key control processes, which are activated in three interactive contexts – single language, dual language and dense code-switching contexts.

Table 1. + indicates the context increases the demand on that control process (++ indicates more demand for more control process); = indicates that the context is neutral in its effects (Adapted from Green & Abutalebi, 2013)

	Interactional Contexts		
Control processes	*Single language*	*Dual language*	*Dense code-switching*
Goal maintenance	+	++	=
Interference control, conflict monitoring and interference suppression	+	++	=
Salient cue detection	=	+	=
Selective response inhibition	=	+	=
Task disengagement	=	+	=
Task engagement	=	+	=
Opportunistic planning	=	=	++

The key assumption of the Adaptive Control Hypothesis is that specific control processes are activated depending on the language context. For example, in a single language context that requires bilingual speakers to communicate in their non-native language, less fluent non-native speakers face frequent interference from their L1. The speaker therefore needs to utilise a process that helps to control interference while maintaining the communication goal in L2 (goal maintenance). The critical control process that is required in this context is control and suppression of the interference from the non-target language (interference control and suppression). When the non-native speaker becomes more proficient in a second language, the activation strength of the second language also increases. Given that this leads to a stronger activation of both L1 and L2, greater control processes are required to monitor the conflict from the non-target language (conflict monitoring) as well as maintaining communicative goals.

The requirement for control processes can drastically change in dual language contexts compared to a single language context. For example, Green and Abutalebi (2013) argued that in a dual language interactive environment, it is likely that the arrival of a new addressee may require the bilingual speaker to switch languages so the communication can be continued and maintained. The arrival of a new addressee is considered to be a salient cue i.e., a cue that enables the speaker to switch to another language. Detection of a salient cue (salient cue detection) is therefore a key control process. The detection of a salient cue and switching into another language also leads to the selective suppression (selective response inhibition) of the ongoing language cues in order to address the communication demands imposed by the new speaker. This context also requires disengagement from the current language (task disengagement) to a new language (task engagement). Conflict monitoring and interference suppression are further central features of this context as switching between languages requires control and suppression of interference.

In contrast to dual language environments where there has been unanticipated switching into another language (due to the arrival of a new speaker), in situations with dense code mixing speakers usually engage in intentional code mixing making use of different adaptive control processes. For example, during code mixing in conversation, it is common for bilinguals to plan the language of specific words (given societal norms and other factors; opportunistic planning). Bilingual speakers may plan well ahead to select words from one language and insert into the syntactic structure of another language.

From the description above it seems clear that dual language contexts necessitate utilisation of many cognitive processes. The Adaptive Control Hypothesis outlines the different cognitive process which may be at play and is flexible enough to be applied to diverse bilingual communication contexts. These control process may also vary in relation to individual differences, and Abutalebi and Green (2013) discuss further issues ranging from potential individual differences to possible behavioural and neuroimaging predictions based on the adaptive control hypothesis. See also Abutalebi and Green (2007) for detailed neuroimaging evidence for control mechanisms.

Cognitive Models of Language Processing: Implications for Bilingual Cognitive Control

A summary of the literature shows that, while cognitive models of bilingualism differ in the language task used as a focus from which they were derived (e.g., word production based on translation in RHM, visual word recognition in BIA+), central to all models is a mechanism that aims to account for the challenges posed by the activation of two or more languages. This is even true for models that assume separate lexicons (e.g., RHM) because the separation exists at the level of lexical representation. At functional level it is suggested that words from two languages compete simultaneously for selection (Kroll et al., 2010).

Specifically for the BIA models (BIA, BIA+), the task schema aims to explain the nature of the attentional mechanisms required for non-selective language access during visual word recognition. However, the language selection problem at the production level has been elegantly explained in the Inhibitory Control model through an efficient inhibitory mechanism controlled by the Supervisory Attentional System (SAS). The more recent Adaptive Control Hypothesis has further separated these mechanisms into eight key control processes that are suggested to be required for bilingual language production depending on various language contexts. Taken together, there seems to be agreement that bilingual language processing necessitates a range of cognitive control mechanisms at both comprehension and production levels.

It seems logical then that the everyday use of cognitive control mechanisms by bilingual speakers would have consequences for their cognitive processing. Indeed a large number of studies have now suggested that the interaction between cognitive and language systems in bilinguals may have effects on the performance of cognitive and linguistic tasks (e.g., Abutalebi & Green, 2007; Kovacs & Mehler, 2009; Martin-Rhee & Bialystok, 2008).

More specifically, in the domain of cognitive control, bilingual children and older adults tend to perform faster than monolinguals on tasks measuring interference suppression and conflict monitoring (e.g., the Simon task). These ‘bilingual advantages’ are inconsistently found in younger adults but are reported to be more robust in children and older adults. These findings have led to a large number of experiments across a variety of tasks and in different age groups with a range of findings from clear bilingual advantages to null effects (see Hilchey & Klein, 2011 for a review).

It is clear that, however intuitive it may be, the evidence for a bilingual advantage in the non-linguistic domain is not unequivocal. One major factor that has been suggested for the failure to replicate these findings is the difficulty in controlling for potentially confounding environmental variables that may influence task performance. For example, socio-economic status (SES) has been reported to be a powerful environmental variable affecting cognitive task performance (e.g., Noble, Norman, & Farah, 2005): Individuals from lower SES tend to perform poorly on cognitive tasks (e.g., Noble, Norman, & Farah, 2005). It has been further claimed that when the effects of SES are controlled, there is no significant difference in performance between bilinguals and monolinguals (e.g., Morton & Harper, 2007; see Hilchey & Klein, 2011 for discussion, and Bialystok, 2009 for a reply to Morton et al., 2007).

Although there are unresolved controversies regarding bilingual effects on non-linguistic cognition, recent reports also suggest that bilingualism influences performance on linguistic tasks. Evidence for these linguistic effects comes from word learning and word recognition tasks. In the domain of word learning it has been reported that bilinguals show an advantage for acquisition of novel words suggesting that bilingualism may affect the functioning of a general language learning mechanism (e.g., Kaushanskaya &Marian. 2009b). However, what is less clear is the precise nature of these bilingual effects. Currently it is undetermined as to whether these effects are observed generally for all bilinguals regardless of age of acquisition or are restricted to bilinguals with an early age of onset of second language acquisition. Equally unclear are the mechanisms that underpin these advantages. For example, is it likely that any enhanced ability to acquire words in bilinguals is influenced by the specific phonological and lexical properties of the novel words?

While these questions on language learning remain unanswered, interestingly, in the domain of auditory word recognition, studies have suggested a bilingual disadvantage (e.g., Rogers, Lister, Febo, Besing, & Abrams, 2006). Evidence predominantly comes from studies measuring bilinguals' ability to recognize words while listening in quiet and naturally noisy (environmental noise) conditions. It has been also reported that these disadvantages are more pronounced when bilinguals are challenged by environmental noise compared to quiet conditions (e.g., Mayo, Florentine, & Buss, 1997). However, these studies have mainly been conducted with immigrant bilinguals and were usually tested in their less fluent, non-native, language (L2). What is not clear from these studies is whether the disadvantage in auditory word (or sentence) recognition is a general disadvantage due to bilingualism, as these studies claim, or rather a side effect of the lower fluency of the bilinguals and the non-native status of the language tested.

Cognitive control, language processing and learning

We have already argued that while controversies surrounding the effects of bilingualism on cognitive control need to be resolved, it is equally important to focus on the effects of bilingualism on other critical linguistic domains such as language learning and recognition. Another critical reason for investigating the effects of bilingualism is due to the fact that cognitive control abilities, language learning/processing are so intimately tied together. For example, it has been suggested that general cognitive control abilities play a crucial role in successful novel word learning as well as for retrieving/accessing words (Bartolotti & Marian, 2011). It could be argued that learning involves production of novel word forms and therefore inhibitory control abilities are critical for supressing irrelevant targets during this task. This assumption is also consistent with both BIA+ and inhibitory control models that indicate a significant activation of inhibitory control abilities during language production and recognition. It is likely that the enhanced activation of task schema in the BIA and BIA+ models or the supervisory attentional system of the inhibitory control models are responsible for any effects of bilingualism in the domain of language processing and learning.

Although these domains are related, unfortunately, except for studies on lexical access measured by picture naming (e.g., Gollan et al., 2005), the effects of bilingualism in these language domains have been largely ignored and under investigated. The four studies reported in this thesis aimed to take a step towards rectifying this and lead to better understanding of the effects of bilingualism on auditory word recognition, word learning and cognitive control. By doing so, it is hoped that this research may further provide evidence to that discussed in the literature on the effects of bilingualism.

Overview of the thesis

The thesis comprises four experimental chapters.

Chapter 2 investigates cognitive control abilities in a very special population of bilinguals: bilinguals of lower socio economic status who were also illiterates. Performance of the bilingual speakers was compared to monolinguals, who were also illiterates and shared the same socio-economic status. This experiment examined whether the reported bilingual advantages in cognitive control could be replicated when bilingualism is associated with poverty. Furthermore, it examines effects of bilingualism on cognition in cultures where bilingualism is highly prevalent and not associated with immigrant status – these are populations that have rarely been studied.

Chapter 3 reports on auditory sentence recognition abilities in bilinguals. This experiment compares the ability of bilingual and monolingual individuals to recognise sentences in their native language (L1). This chapter therefore extends the previous literature on this topic by examining whether bilingualism is associated with a word recognition disadvantage even when tested in L1 and whether bilingualism hampers sentence recognition ability especially in the presence of background noise.

Chapters 4 & 5 investigates the effects of bilingualism on novel word learning. **Chapter 4** specifically investigates how a later age of second language acquisition interacts with the ability to acquire novel words. **Chapter 5** further studies novel word learning in bilinguals examining whether bilingual advantages in novel word learning are constrained by the phonotactic patterns and phonological neighbourhood size of the given novel word.

In sum, all four chapters investigate one key issue – the effects of bilingualism on language and cognition. In **Chapter 6,** the concluding chapter of this thesis, the effects of bilingualism in relation to the tasks investigated in the individual chapters will be discussed in the light of contemporary evidence from bilingual literature. In addition, both theoretical implications for cognitive models of bilingual language processing and broader implications will be presented.

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Chapter 2

Effect of socio-economic status on cognitive control in non-literate bilingual speakers

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Abstract

Previous research has suggested that the advantages for cognitive control abilities in bilingual speakers are attenuated when socio-economic status (SES) is controlled (e.g., Morton & Harper, 2007). This study examined the effect of SES on cognitive control in monolingual and bilingual individuals who lived in adverse social conditions with low levels of literacy. We tested monolinguals and bilinguals using the Simon and Attentional Network task while controlling for two potential confounding factors: SES and literacy. Bilinguals showed overall faster response times than monolinguals on both tasks. However, no bilingual advantage was found for conflict resolution on the Simon task and attentional networks on the Attentional Network task. The overall bilingual effects provide evidence for a bilingual advantage even among individuals without literacy skills and of very low SES. This indicates a strong link between bilingualism and cognitive control over and above effects of SES.

Introduction

Research that has been conducted in the past decade on the relationship between bilingualism and cognitive ability has focused on whether bilinguals possess superior non-linguistic cognitive control abilities compared to monolinguals (e.g., Abutalebi & Green, 2007; Bialystok, Craik, Klein, & Viswanathan, 2004; Costa, Hernandez, & Sebastián-Gallés, 2008). This stems from the idea that the bilingual advantage originates from the bilingual's need to inhibit their non-target language which arises due to the parallel activation of all known languages in the lexicon (e.g., Green, 1998, Bialystok, Craik, Klein, & Viswanathan, 2004). Studies have suggested a bilingual advantage in a range of tasks. For example, bilinguals have been demonstrated to show superior performance in task switching (Prior & Macwhinney, 2008), working memory (Bialystok, Poarch, Luo, & Craik, 2014), conflict monitoring (Costa, Hernandez, Costa-Faidella, & Sebastián-Gallés, 2009), conflict resolution and alerting (Costa, Hernandez, & Sebastián-Gallés, 2008), and on non-verbal auditory executive function tasks (Foy & Mann, 2013).

While there is a widespread interest in examining the specific mechanisms underlying the bilingual advantage, the extent to which bilingualism has been linked to superior cognitive ability has led to considerable criticism (e.g., Hilchey & Klein, 2011). Indeed, recent research has produced conflicting reports with some studies indicating no differences between bilinguals and monolinguals for tasks measuring non-linguistic cognitive control (e.g., Paap & Greenberg, 2013). In one of the most exhaustive reviews on the effects of bilingualism on cognition, Valian (2015) emphasised two possibilities for those reports which do not find a bilingual advantage: a) bilingualism does not exert any cognitive control benefits and/or b) bilingualism exerts certain cognitive control benefits, however, these effects are similar to those resulting from other forms of expertise, such as being a professional musician, a juggler, or a long-term meditator. It is therefore often difficult to disentangle those skills experimentally, when monolingual controls may have life experiences (e.g., musical training) which also positively affect cognitive abilities.

While the debate on how different life experiences may influence cognitive abilities is largely unresolved, it has been also suggested that the apparent benefits of bilingualism may stem from other confounding factors, such as socio-economic status (SES). For example, Morton and Harper (2007) criticised past studies (e.g., Bialystok & Marin, 2004) for inadequately controlling SES and suggested that the better performance of bilinguals may be due to their higher SES (relative to monolinguals) rather than their bilingualism. Engel de Abreu, Cruz-Santos, Tourinho, Martin and Bialystok (2012) suggest that the confounding effect of SES has two major implications. First, it would mean that the bilingual advantage emerged as a result of higher SES. Second, it would also indicate that only bilinguals from higher SES would be expected to outperform monolinguals. The research reported here sought to investigate this issue by examining whether a bilingual advantage in cognitive control was evident in individuals from lower SES backgrounds. Hence the present study examined cognitive control abilities in bilingual individuals of lower SES and compared their performance with monolingual individuals from a similarly low SES background.

Effects of SES on bilingual cognitive control

SES exerts a profound impact on specific cognitive control tasks such as those measuring alerting and executive attention (Mezzacappa, 2004). The likelihood of a potential confound of SES in bilingual cognitive control measures was first reported by Morton and Harper (2007). Bialystok, Craik, Klein and Viswanathan (2004) administered a Simon task with bilingual and monolingual adults and found an advantage for bilingual adults in conflict resolution. Martin and Bialystok (2003) had earlier reported a similar effect in children. In the Simon task participants are required to press appropriate computer keys to correspond to red or blue coloured boxes. The boxes are either presented on the same side of the computer screen as the appropriate colour response key (spatially congruent) or on the opposite side (spatially incongruent). Participants typically respond faster to congruent than incongruent trials. The difference in response time between incongruent and congruent is considered to be an index of conflict resolution abilities (see below for more detail on this task). When Morton and Harper (2007) used the Simon task with children who were matched for SES, in contrast to Martin and Bialystok (2003), they found identical performance for bilingual and monolingual children. Moreover, they found an association between higher SES and better performance on the Simon task (SES was negatively correlated with a reduced Simon effect), regardless of language status. However, Bialystok (2009) suggested that the failure to obtain any significant differences between the two language groups may have been rooted in developmental differences as participants in Morton and Harper (2007) were 1.5 years older than the participants in Martin and Bialystok (2003). She hypothesised that by the age of 7 years monolingual children may have acquired similar executive function abilities to bilingual children. Although developmental differences offer a reasonable explanation, past studies have also suggested bilingual advantages for children at 8 years. Therefore, it is unclear why a bilingual advantage would not be present at 7 years and re-emerge for children at the age of 8 years (Hilchey & Klein, 2011).

In their review, Mindt et al. (2008) suggested that bilingual advantages may be difficult to replicate with bilingual individuals from countries where bilingualism is not typically associated with higher SES. They also note that in previous studies that have reported a bilingual advantage with children from low SES, the advantage emerged only after effects of SES were controlled for. For example, Carlson and Meltzoff (2008) showed that bilingual children from comparatively lower SES backgrounds demonstrated advantages over monolingual children from privileged social background (higher SES) on a range of executive function tasks (e.g., advanced dimensional change card sort, simon says, visually cued recall) only after parental education was controlled (as a proxy for SES). Although it is true that the effects of bilingualism emerged only when SES was controlled, the composite raw scores of all executive function tasks indicated no significant group difference between children from lower and higher SES. Therefore, the fact that lower SES bilingual children showed similar performance on raw scores to higher SES monolingual children indicates that perhaps some of the cognitive disadvantages of lower SES may be compensated for by superior cognitive control mechanisms resulting from their bilingual experience (Carlson & Meltzoff, 2008). This finding would therefore contradict the earlier claim that bilingual advantages may be absent in individuals from lower SES.

In a similar study, Engel de Abreu et al. (2012) specifically studied the ability to resolve cognitive conflict in lower SES monolingual and bilingual children from Luxembourg and Portugal. An assessment of poverty indicator found that the bilingual children were more disadvantaged than monolingual children. The authors predicted that bilingual experience specifically influences the ability to resolve conflict (a domain specific advantage) rather than providing facilitation of overall cognitive mechanisms (a domain general advantage). As predicted, the bilingual children showed a specific advantage on cognitive control tasks (selective attention - Sky Day Search task; interference suppression - Flanker task) and not on abstract reasoning (Ravens Coloured Progressive Matrices) and working memory measures (Odd-One-Out; Dot Matrix). This finding therefore also supports the position that bilingual advantages for conflict resolution in children cannot be accounted for solely by differences in SES.

In order to further dissociate the role of SES in bilingual cognitive control, Calvo and Bialystok (2013) studied 6 to 7 year old bilingual and monolingual children using parental education as proxy for SES. A range of language (e.g., Peabody Picture Vocabulary Test) and cognitive tests (e.g., Nonverbal Visual Attention and Flanker task) were administered to assess language and executive functioning. Their results suggested that both SES and bilingualism had an overall effect on language and cognition; however this effect was not in the same direction. SES was associated with decreases in both language and executive functioning performance, whereas bilingualism was associated with a decrease in language but increase in executive functioning abilities. This evidence suggests that the effect of SES on cognitive ability may not override the effect of bilingualism.

While the role of SES on bilingual cognitive control in children has received some attention, its role has been under-researched in adults. The bilingual advantage on tasks measuring executive function has been replicated by some studies with middle aged and older adults (e.g., Bialystok, Craik, & Luk, 2008; Salvatierra & Rosselli, 2010). However, in these studies not only are bilingual adults are often high SES, but SES is rarely explicitly controlled. Therefore not only is it unclear whether the bilingual advantage manifests only in higher SES populations, but also the extent to which it may be a confound of SES in adults (Hilchey and Klein, 2011). However, it is often hard for factors such as cultural practices, differences in life experiences between language groups, immigrant status, SES and literacy to be controlled. Moreover, most bilingual studies tend to focus on bilinguals from an urban middle class background. In many parts of the world, bilingualism is not associated with immigrant status or classroom experience but is a part of the everyday living experience. For example, in rural southern India, where this study was conducted, a significant number of people living in (interstate) border areas are bilinguals who belong to a lower SES population. In these areas, both bilinguals and monolinguals share similar social and cultural values and often both monolingualism and bilingualism co-occur with poverty and illiteracy. This linguistic and socio-economic background provides an ideal situation for studying the role of bilingualism in cognitive control with matched low SES groups. It also can provide evidence from cultures and individuals that have been less studied in the bilingual cognitive control literature (rural bilinguals and monolinguals).

Hence, the study reported here examined performance on cognitive control tasks in bilingual and monolingual individuals who were living in very difficult social conditions (from lower SES on the verge of poverty) and were from a non-literate background with no acquisition of literacy through formal academic education.

We administered two of most commonly used tasks to assess executive function. Experiment 1 used the Simon task (Simon & Berbaum, 1990; Simon & Small, 1969; Simon & Wolf, 1963) and Experiment 2 the Attentional Network task (Fan, McCandliss, Sommer, Raz, & Posner, 2002; for use in bilingual research see Costa et al., 2008). Both tasks are argued to measure conflict resolution abilities (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Costa et al., 2008).

As noted above, in the Simon task (Simon & Berbaum, 1990; Simon & Small, 1969; Simon & Wolf, 1963), spatially congruent and incongruent stimuli (e.g., coloured boxes – red and blue) are presented to the participants with two response keys associated for each stimulus (e.g., right sided key for the red box and left sided key for the blue box). Responding to the incongruent stimuli while ignoring the spatial conflict is one of the key aspects of this task. Due to the conflicting responses present in the incongruent stimuli, this condition leads to a comparatively longer reaction time compared to the congruent condition (see also Lu & Proctor, 1995; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002 for more detail on this topic). The difference in response times between incongruent and congruent conditions is described as the Simon effect (e.g., Simon & Berbaum, 1990).

The Attentional Network Task (Fan et al., 2002) is a combination of the flanker task (Eriksen & Eriksen, 1974) and the cue reaction time task (Posner, 1980). It is argued that this is one of the best tasks for assessing inhibitory control abilities (e.g., Costa, Hernandez, & Sebastián-Gallés, 2008). In this task, three types of spatial stimuli (congruent, incongruent and neutral) are presented above or below a fixation cross. The stimuli are usually presented as a set of five arrows either pointing right or left. Responses are based on the direction of the centre arrow. The centre arrow can either point in the same direction as the other (flanker) arrows (congruent condition) or in a different direction (incongruent condition). Response times for the incongruent conditions, where there is conflicting information from Flanker tasks is longer than for the congruent conditions, where there is no conflict. In addition to measuring conflict resolution/inhibitory control (as also assessed by the Simon task), the Attentional Network task also measures other critical cognitive control abilities such as the executive network, alerting and orienting mechanisms. The executive network is measured by calculating the difference between incongruent and congruent trials (conflict effect). Generally, participants respond faster for congruent than incongruent trials. The alerting mechanism is studied by presenting a cue before the flanker arrows appear which indicates that the arrows are about to appear. The alerting effect is the difference in performance between trials without an alerting cue (no cue) and those with an alerting cue (double cue) (generally responses are faster for trials preceded by an alerting cue). Orienting mechanisms are studied by presenting a cue that directs the participants to the location (e.g., above or below the fixation cross) of the flanker arrow. The orienting effect is the difference in the participants' performance between trials preceded by a centre cue (without any cue to spatial orientation) and those with a spatial cue indicating a spatial orientation.

We predicted that if bilingualism improves cognitive control, and specifically confers an advantage for conflict resolution, then bilinguals may exhibit superior performance compared to monolinguals despite their shared lower SES. For the Simon task, this would be manifested by a specific advantage for trials with conflict (conflict resolution/interference suppression effect) or as an overall bilingual advantage for both trials with and without conflict (global effect). For the Attentional Network task, we expected the bilingual advantage to be manifested in a similar way to the Simon task: either a specific advantage for trials with conflict and/or an overall advantage. Additionally, we predicted that if bilingualism facilitates alerting networks (the difference in reaction time between trials preceded by no cue and double cue) and orienting networks (the difference in reaction time between trials preceded by centre cue and spatial cue), then, we expected larger differences for lower SES bilinguals for both networks compared to monolinguals.

Experiment 1

In Experiment 1, we administered the Simon task to bilingual and monolingual speaker groups to examine whether bilinguals from lower SES performed better than monolinguals from a similar social background.

Method

Participants and demographic details

36 individuals participated, 18 bilingual speakers and 18 monolingual speakers (see Table 1). Participants were bilingual and monolingual low SES, illiterate, middle-aged adults recruited from rural villages of the southern Indian state of Kerala. According to the "United Nations Department of Economic and Social affairs Statistics Division" (Retrieved from http://unstats.un.org/unsd/demographic/sconcerns/education/ed3.htm, see concepts and definitions under standards and method section) an illiterate person is one who cannot, with understanding, both read and write a short, simple statement on his or her everyday life (see also Ashaie & Obler, 2014). All the participants in the current study met this criterion (see below) not having had the opportunity to acquire literacy through schooling.

The bilingual and monolingual participants were native speakers of Malayalam (L1). The bilingual participants spoke Tulu (L2) as their second language acquired before the age of 6. The bilingual participants' second language proficiencies (speaking and understanding) were assessed by administering oral questions based on a language proficiency rating scale (Chengappa, Shivashankar, Nair, Nayak, & Arvind, 2011). Socio-economic status (SES) of the participants was assessed using four critical indicators (1. pooled monthly income, 2. highest level of education, 3. occupation, and 4. family property) by using the socio-economic status scale (Venkatesan, 2011). Demographic and background data of participants are given in Table 1.

Table 1. Demographic and background data of participants as means and standard deviations (in parentheses).

Demographic data	Monolinguals	Bilinguals	p
Age (years)	50.83 (4.25	51. 22 (3.93)	.777
SOCIO ECONOMIC STATUS			
Overall SES			
	4.16 (0.38)	4.11 (0.32)	.641
Pooled monthly income[b]	1.35 (.49)	1.47 (.51)	.508
Literacy[c]	1.11 (.33)	1.17 (.39)	.640
Occupation[d]	1.88 (.60)	1.70 (.68)	.430
Family properties[e]	1.17 (.39)	1.29 (.46)	.434
L2 acquisition age (speaking)	__	5.05 (0.41)	__
Proficiency ratings[f]			
Speaking	__	3.83 (0.38)	__
Listening	__	3.88 (0.32)	__

Notes
N = 18 for each group, p = significance of t-test (2 tailed).
[a]Scale from 0 (lowest SES) to 20 (highest SES).
[b]Scale from 1 (Rs. 5000 or below) to 5 (Rs. 20001 or above).
[c]Scale from 1 (illiterate) to 5 (Post Graduation or above).
[d]Scale from 1 (unskilled/daily wager) to 5 (Specialised/Class 1 services).
[e]Scale from 1 (below Rs.50,000) to 5 (above Rs 500,000)
[f]Rating from 0 = not proficient to 4 = highly proficient

Task & Procedure

In order to make the participants more comfortable and the testing environment less intimidating, all participants were familiarised with the computer by playing music videos in their native language (Malayalam) for five minutes.

A Simon task was administered to all participants using the DMDX display system (Forster & Forster, 2003) on a laptop computer. The test included 20 practice trials and 112 experimental trials. These trials were presented in four blocks which consisted of 28 trials each, of which half of the trials were congruent (50%) and half incongruent (50%). The order of the presentation was randomised for each participant. Each trial consisted of a presentation of a fixation cross (+) in the centre of the computer monitor maintained on the screen for 250 milliseconds (ms), followed by a coloured (red or blue) square presented on the left or the right side of the screen for a duration of 2000 ms or until a response from the participant. Two keys were labelled with a red (m, on the right) or blue (z, on the left) sticker to be response keys. In congruent conditions, the coloured square appeared on the same side as the response key (e.g. a red square appearing on the right side of the screen requiring a response from the red key on the right). In incongruent conditions the coloured square appeared on the opposite side to the response key (e.g., a red square appearing on the left side of the screen but still requiring a response from the red key on the right). Participants were asked to pay attention to the coloured squares regardless of their position and press the appropriate coloured button depending on the colour of the square. The entire task took about 20-25 minutes.

Analysis

First, reaction times above and below 3.0 standard deviations from the mean of each subject for each condition were removed. We also eliminated reaction times longer than 1500 ms and shorter than 300 ms. In total less than 3% of responses were removed. The data from three bilingual participants and two monolingual participants were eliminated due to high error rates (> 40%). RT analysis was carried out only for trials with correct responses. The results are reported in Table 2. Response latencies were analysed with a 2 (trial type – congruent vs. incongruent; within subjects) by 2 (language group – bilinguals vs. monolinguals) Mixed Analysis of Variance.

Results

Table 2. Mean response times (RT), error rates and standard deviations (in parentheses) for bilinguals and monolinguals.

Trial type	**Bilinguals**		**Monolinguals**	
	RT (SD)	Errors (%)	RT (SD)	Errors (%)
Congruent	722.73 (20.36)	.05 (.05)	861.79 (144.12)	.09 (.07)
Incongruent	743.33 (129.77)	.08 (.05)	897.80 (135.33)	.10 (.08)

The error analysis found no significant effect of group (bilinguals and monolinguals) (F (1, 34) = 7.06, p = .229) or trial type (congruent and incongruent) (F (1, 34) = 5.45, p = .258). As expected, there was a significant main effect of trial type (F (1, 34) = 4.54, p = .040, η^2=.109) with congruent trials significantly faster than incongruent trials. There was also a significant main effect of group (F (1, 34) = 13.25, p = .001, η^2=.264): bilinguals exhibited a global advantage for response times compared to monolinguals. Although bilinguals appeared to show a reduced interference effect (the difference between congruent and incongruent trials; bilinguals (20.60 ms) compared to monolinguals (36.01 ms), the interaction between group and trial type was not significant [F (1, 34) = .337, p = .565, η^2=.009].

In order to confirm the absence of a reduced Simon effect in bilinguals, RT and errors were further combined (mean RT for each participant divided by the percentage of correct responses) to obtain an inverse efficiency score (IES). The IES can be used as a measure to confirm results obtained from traditional RT analysis (Bruyer & Brysbaert, 2011). However, this can only be used in the absence of a speed-accuracy trade off and when error rates are low (< 10 %; Townsend & Ashby, 1978). In order to identify whether there was a speed-accuracy tradeoff, the RT data for all participants was correlated with accuracy. This correlation was not significant indicating that a speed-accuracy tradeoff was unlikely ($r = .10$, $p=.405$). Our data fulfilled both these criteria. The results confirmed the previous findings from RT analysis revealing a main effect of trial type (congruent trials faster for both language groups) ($F (1, 34) = 4.52$, $p = .041$, $\eta^2=.117$) and a main effect of group ($F (1, 34) = 8.25$, $p = .007$, $\eta^2=.195$), and once again the interaction between group and trial type was not significant ($F (1, 34) = .141$, $p = .710$, $\eta^2=.004$] .

Discussion Experiment 1

There were two key findings from Experiment 1. First, bilinguals exhibited a significant advantage over monolinguals for both trials with conflict (incongruent) and those without conflict (congruent): a global bilingual advantage. Second, although there was an overall bilingual advantage, the group versus trial type interaction was not significant. In other words, bilinguals did not show reduced interference for incongruent trials relative to congruent trials – they were not superior in conflict resolution. A significant global response time advantage for bilinguals with no advantage for conflict resolution is not uncommon and has been an issue of controversy in the past (e.g., Hilchey & Klein, 2011), we will return to this in the General Discussion.

Experiment 2

Method

The same participants, who completed a Simon task, were tested again with the Attentional Network task. The testing was carried out in a second session one hour gap between the first and second tasks on the same day.

Task & Procedure

We administered the Attentional Network task using the DMDX display system (Foster & Foster, 2003) on a laptop computer. We replicated the task used by Costa, Hernandez and Sebastián-Gallés (2008) which was developed by Fan et al. (2002). The experimental conditions involving cue type consisted of trials with no cue, centre cue, double cue, or spatial cue.

The entire task consisted of 288 trials with 12 different experimental conditions presented in three different blocks. Each experimental condition was represented by 8 trials in one block leading to a total 96 trials per block. Before the testing began, the participants saw 24 practice trials. Following the presentation of practice trials the participants were presented with Flanker stimuli (arrows pointing either right or left) appearing on the computer screen for 1700 ms preceded by a fixation cross. The target stimulus always appeared as a set of five congruent, incongruent or neutral stimuli (33% of each trial type), including a central arrow pointing either towards the right or left. The participants were instructed to locate the direction of the centre arrow as quickly and as accurately as possible. Two keys (‘m’ on the right and ‘z’ on the left hand side of the keyboard) were assigned as response buttons. The response buttons were masked with a sticker depicting an arrow pointing to the right (m) or left (z). Participants were asked to press the right button if the centre arrow pointed right and left button if the centre arrow pointed left. The entire task lasted for about 20-25 minutes. The order of the stimuli was randomised for each participant.

In each condition there was one central arrow pointing left or right. In the neutral condition this arrow was flanked by lines without arrowheads. In the congruent condition the flankers were arrows pointing in the same direction as the target and in the incongruent condition the flankers were arrows pointing in the opposite direction.

There were four different cue conditions – (i) no cue, (ii) centre cue, (iii) spatial cue and (iv) double cue. In the no cue condition only the fixation cross was presented. In the centre cue condition, the cue (an asterisk) was presented centrally above the fixation cross (and hence did not cue location) before presentation of the flanker stimulus. In the spatial cue condition the cue was presented to the left or right of the screen to cue the direction of the subsequent arrow. In the double (alerting) cue condition cues (asterisks) appeared above and below the fixation cross simultaneously in order to alert the participant to the presentation of the next flanker arrows. All three cue types remained on the computer screen for a duration of 100 ms. The target flanker arrows appeared on the screen after a duration of 400 ms. The flanker arrows remained in the spatial location for 1700ms or until the participant made a response (see also Costa, Hernandez, & Sebastián-Gallés, 2008).

Analysis

The RT data was trimmed using a same procedure to that of Experiment 1 resulting in the removal of less than 5% of the data. Three bilingual and two monolingual participants exhibited high error rates (> 40 %) and therefore their data were excluded from the analysis. The data were analysed using 2 (language groups: bilinguals vs. monolinguals)* 3 (trial type: congruent, incongruent, neutral)* 4 (cue type: no cue, centre cue, double cue, spatial cue) repeated measures of analysis of variance (ANOVA) with language groups as between subject factors and trial type and cue type as between subject factors.

Table 3. *Mean response times (RT), and standard deviations (in parentheses) for flanker type and cue type in bilinguals and monolinguals.*

Cue type	**Bilinguals**				**Monolinguals**			
	Congruent	Incongruent	Neutral	CE[a]	Congruent	Incongruent	Neutral	CE[a]
No cue	992 (139)	1023 (183)	1007 (174)	31	1023 (120)	1105 (126)	1106 (141)	82
Double cue	974 (166)	1006 (155)	986 (176)	32	1016 (150)	1097 (99)	1042 (123)	81
Centre cue	982 (166)	1024 (144)	975 (155)	42	1050 (161)	1103 (120)	1094 (143)	53
Spatial cue	951 (136)	997 (164)	920 (152)	46	1013 (134)	1085 (110)	1115 (148)	72
Alerting effect	18	17			7	8		
Orienting effect	31	27			37	18		

Notes
NC-No cue, DC-Double cue, CC- Centre cue, SC-Spatial cue
[a]Conflict effect(CE) was calculated by measuring the reaction time difference between incongruent vs. congruent trials
Alerting effect was calculated by measuring the reaction time difference between no cue trials from double cue trials
Orienting effect was calculated by measuring the reaction time difference between centre cue trials from spatial cue trials

Results

The results are reported in Table 3. The error analysis found no significant effect of group (bilinguals and monolinguals) (F (1, 34) = .156, p = .729), or cue type (F (3, 426) = .792, p = .499). The effect of trial type (congruent, incongruent and neutral) was close to significant (F (2, 284) = 2.32, p =.099), None of the two or three way interactions were significant (group and trial type (F (2, 284) = 2.30, p =.102); group and cue type (F (3, 426) = .164, p = .920); group, trial and cue type (F (6, 426) = 0.103, p = 0.749).

In the analysis of reaction time, there was a significant main effect of trial type ([F (2, 68) = 5.37, p = .006, ηg^2=.026]), and of group: bilingual speakers were significantly faster (988ms) than monolingual speakers (1085ms) (F (1, 34) = 7.34, p = .010, ηg^2=.080]). However, the interaction between group and trial type was not significant (F (2, 68) = 1.38, p = 0.25, ηg^2 = .007). There was also no significant main effect of cue type (F (3, 102) = 1.31, p = 0.27, ηg^2=.005]) nor two way interactions between group and cue type (F (3, 102) = 1.31, p = 0.27, ηg^2 = .005), trial and cue type (F (6, 204) = 0.37, p = 0.89, ηg^2 = .003) or group, trial and cue type (F (6, 204) = 0.43, p = 0.85, ηg^2 = .003). Analysis for speed-accuracy tradeoff once again indicated that this was unlikely (r = .08, p=.384). IES results replicated a main effect of trial type (congruent trials faster for both language groups) (F (2, 34) = 6.72, p = .001, η^2=.154) and a main effect of group (F (1, 34) = 9.74, p = .001, η^2=.175). The interaction between group and trial type was not significant (F (2, 88) = .083, p = .314] and group and cue type were not significant (F (3, 102) = .041, p = .517] .

Figure 1 shows the three different attentional mechanisms tapped in this experiment. Although the conflict effect (congruent vs incongruent trials) appeared reduced for bilinguals (see Figure 1), the lack of significant interaction between group and trial type indicated that this difference was not reliable. There were also no differences between groups for the alerting (no cue vs double cue) and orienting (centre vs spatial cue) effects indicated by the lack of a significant interaction between cue type and group.

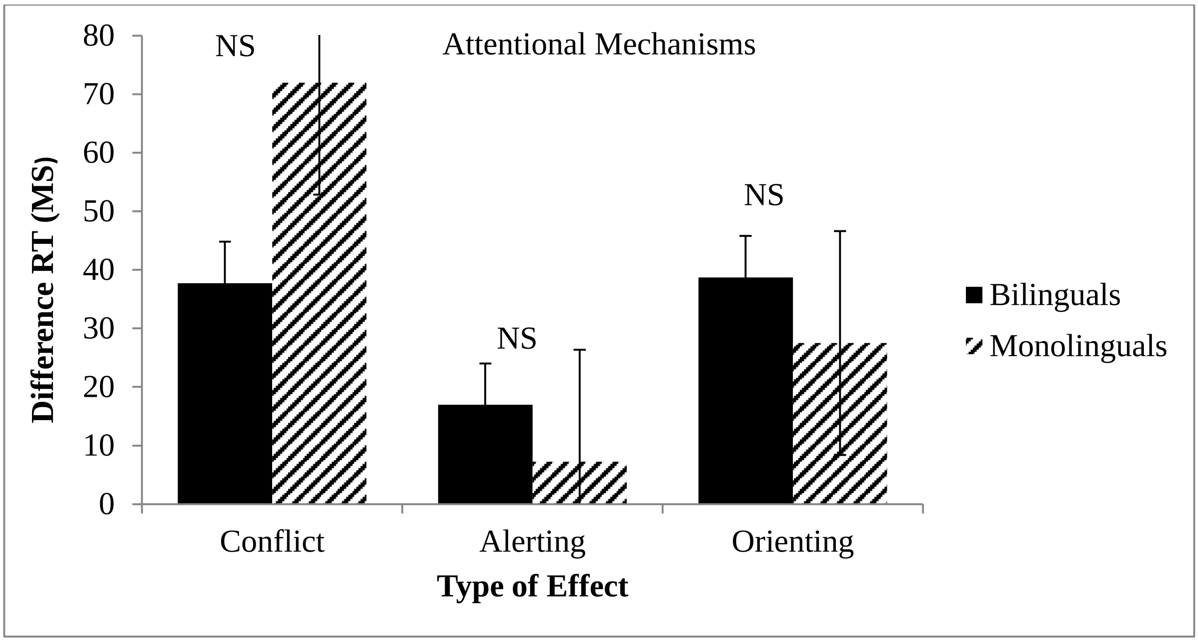

Figure 1. Mean differences in reaction times across conditions for three attentional network effects for both bilinguals and monolinguals. Error bars indicate standard error (SE). NS: Non-significant.

Discussion Experiment 2

Experiment 2 assessed cognitive control mechanisms in bilinguals and monolinguals using the Attentional Network task. Critically, the results once again, confirmed a global bilingual advantage, as we found in the Simon Task. This is consistent with the findings of Costa et al. (2008) and supports the idea of a bilingual advantage even for trials without conflict (congruent trials). Costa et al. (2008) indicated that a bilingual advantage for congruent trials demonstrates bilinguals' ability to monitor conflict, in addition to interference suppression being important for incongruent trials, and therefore indicating an advantage for both conflict resolution and monitoring in bilinguals. However, the final analysis with the three attentional networks (executive, alerting and orienting) showed no significant difference between the language groups. Although there was a reduced conflict effect for bilinguals compared to monolinguals, the lack of statistical significance suggested that the advantage of bilingualism is not specifically constrained to inhibiting trials with conflict. Similarly, the non-significant difference between the alerting and orienting effect indicated that the benefit of a cue to orient/alert to the onset of the stimulus is not affected by bilingualism.

General Discussion

This study assessed the effect of bilingualism on the performance of illiterate bilinguals and monolinguals from lower SES on the Simon and the Attentional Network (Flanker) task. The results were clear: There is a processing advantage for bilingual speakers even when they are of low SES. For both the Simon task and the Attentional Network task, bilinguals responded more quickly than monolinguals.

This global bilingual advantage is sometimes referred to as the bilingual executive processing advantage (BEPA) and may have emerged due to enhanced conflict monitoring mechanism in bilinguals. For example, Costa et al. (2009) suggested that because tasks that measure cognitive control involve both trials with and without conflict, participants need to constantly monitor conflict regardless of the trial type. Therefore an overall advantage could reflect bilinguals' efficient monitoring mechanisms. It is also possible that such a monitoring mechanism may be activated when a bilingual's language context involves two cognate languages. Speaking in languages with close phonological familiarity may involve continuous activation of monitoring mechanisms to prevent interference. Indeed, our bilinguals spoke cognate languages (Malayalam and Tulu). However, this hypothesis needs to be further tested considering the language context of these bilinguals.

For the Attentional Network Task, Costa, Hernández, Costa-Faidella and Sebastián-Gallés (2009) have suggested a more robust conflict effect when a lower percentage (33%) of congruent trials are used compared to the relatively high percentage (50%) of congruent trials in the Simon task. Although the Attentional Network Task in our study consisted of only 33%

of congruent trials which is much lower than the 50% congruent trials in the Simon task, this difference was not enough elicit a significant conflict effect between bilinguals and monolinguals. Furthermore, our results also found no evidence for a relationship between bilingualism and other attentional networks such as the alerting and orienting networks. These results are in contrast with the findings of Costa, Hernández, Costa-Faidella and Sebastián-Gallés (2009) which suggested a bilingual advantage specifically for conflict and alerting effects. It is unclear why we obtained this contradictory pattern of results however, our findings from both the Simon and Attentional Network Task are in line with the previous literature indicating a more general effect of bilingualism (global effects) rather than a specialised conflict or alerting effect (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009).

The major focus of this study was the fact that the participants were bilinguals and monolinguals who were both economically and socially disadvantaged and with no opportunity to acquire any formal literacy skills. There is evidence that suggests that living in adverse social conditions can affect performance on tasks measuring executive function (e.g., Noble, Norman, & Farah, 2005). Both our monolingual and bilingual participants would be expected to have suffered equally on tasks measuring cognitive control due to the influence of their social environment. Nonetheless, there was an advantage for bilinguals compared to monolinguals. This has two implications: first, these bilinguals from lower SES benefitted from bilingualism on cognitive control tasks indicating that bilingualism has independent effects on performance of such tasks. Second, it suggests that the bilingual effects found in previous studies were not a mere reflection of the benefits of high SES in bilingual groups as these benefits extend to individuals from lower SES. Importantly, the concerns regarding SES have previously been addressed mainly in studies conducted with children (e.g. Morton & Harper, 2007). However, we focused, for the first time, on middle aged adults and our results therefore further weaken support for the proposal that the bilingual advantage is no longer evident when SES is controlled in adults.

The absence of literacy in these participants is also important because literacy skills are likely to affect cognitive performance (Kave, Eyal, Shorek, & Cohen-Mansfield, 2008). However, Kave et al. (2008) also note that, in multilinguals, language status may correlate with cognitive ability more than with literacy. Although our results found an advantage for bilinguals with no literacy, we cannot tease apart the specific effect of literacy on cognitive ability as lower SES and illiteracy are confounded in our study (and indeed often will be). The confounds can be avoided in future by studying, for example, bilinguals who had acquired literacy skills but remain lower SES and also higher SES bilinguals with no formal literacy skills. Although we measured SES using a culturally appropriate socio economic scale, it is possible that measuring SES in other ways may also influence the results. For example, Abutalebi, Guidi, Borsa, Canini, Della Rosa, Parris, & Weekes (2015) assessed socio-economic status of their participants using a 10 point rating scale developed by the MacArthur Foundation (http://www.macses.ucsf.edu/research/socialenviron/sociodemographic.Php) that measures participant's subjective perception about his/her socio-economic status, education and family income. It is possible that measuring these could have led to further sub grouping of participants. If possible, future studies should aim to compare participants based on a graded socio economic scale in order to better understand how bilingual participants across a range of SES perform on cognitive control tasks.

Although it is premature to consider bilingualism as a protective mechanism against the negative cognitive effects of SES in these individuals, evidence from developmental studies offers promise in this direction suggesting protective effects of bilingualism against the cognitive effects of poverty (de Abreu et al., 2012). However, this needs to be further rigorously investigated in bilingual adults. The nature of the bilingual community may also be significant (Bialystok, 2015) in further understanding the implications of the results for ‘cognitive reserve’. For the participants in the present study, a bilingual experience was not associated with a classroom or immigrant status but was part of everyday life. The societal practices of these bilingual communities had encouraged bilingualism for centuries and further promoted bilingualism through cross-cultural marriages. This aspect of bilingualism is relevant as increasingly researchers have treated bilingualism as a categorical variable (Luk & Bialystok, 2013) and have ignored multiple dimensions (societal and cultural) with most emphasis placed on experimentally controlling daily language use, proficiency and dominance.

These individuals have treated bilingualism as an asset, and considering their social background this may be one of the few life experiences that may benefit cognition, in contrast to urban bilinguals who often live in an environment with a host of potentially positive life experiences for cognition (e.g., video game playing, musical experience). Isolating the effects of bilingualism from a vast number of potentially beneficial life experiences is challenging (Abutalebi & Clahsen, 2015; Valian, 2015), however, our results suggests a preliminary indication of the independent effects of bilingualism in the absence of an enriched life style, high educational qualification attained for immigrant status, classroom bilingual experience and/or literacy. These results have implications when considering bilingualism as a lifestyle factor associated with increased cognitive reserve (Bialystok, 2015) as well as for shaping both educational and health policy in the context of bilingualism and poverty.

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Chapter 3

Recognition of sentences in noise: Is there a bilingual disadvantage?

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Abstract

It had been suggested that bilinguals perform more poorly on word recognition in noise than monolinguals. However, it was not clear if bilingualism was associated with a disadvantage beyond the word level extending to sentence recognition. This study investigated the ability of Malayalam-Tulu bilinguals and Malayalam monolinguals to recognise and repeat sentences in their native language (L1) in the presence of a non-linguistic distractor (background noise). Both monolinguals and bilinguals demonstrated similar sentence recognition scores suggesting that bilingualism is not associated with a cost for sentence recognition in the presence of noise. Our results therefore contrast with previous studies showing a disadvantage for bilinguals for word recognition in noise (e.g., Mayo, Florentine, & Buus, 1997).

Introduction

It has long been debated whether bilingualism is an advantage or a handicap (e.g., Darcy, 1953). Bilingual speakers have been reported to show advantages compared to monolinguals in a number of non-linguistic domains, including inhibitory control and conflict resolution (e.g., Abutalebi et al., 2011; Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006; Bialystok & Depape, 2009; Carlson & Meltzoff, 2008; Costa, Hernandez, & Sebastián-Gallés, 2008). In contrast, it has been suggested that bilinguals exhibit a general disadvantage for linguistic processing tasks (e.g., Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Ivanova & Costa, 2008). For example, bilinguals experience more tip of the tongue errors than monolinguals (Gollan & Acenas, 2004) as well as a disadvantage for tasks involving lexical access such as picture naming (e.g., Gollan, Montoya, Fennema-Notestine, & Morris, 2005). Studies have also reported that bilinguals exhibit poorer word recognition scores in sub-optimal listening environments (e.g., noise) (e.g., Rogers, Lister, Febo, Besing, & Abrams, 2006; Tabri, Chacra, & Pring, 2011).

The explanation often put forward for the non-linguistic advantage shown by bilinguals relates to their experience in supressing interference from the irrelevant language during language production. This experience is argued to result in more efficient cognitive control mechanisms. However, it is unclear why bilinguals suffer a specific linguistic processing disadvantage compared to monolinguals. In particular, a bilingual disadvantage for auditory word recognition in noise is perplexing given that identifying words by suppressing noise can be considered similar to the interference suppression task during bilingual language production. Interestingly, recent studies have pointed out that both bilingual children (Filippi, et al., 2014) and adults (Filippi, Leech, Thomas, Green, & Dick, 2012) are better able to control linguistic interference from distractor sentences during spoken language comprehension. These advantages once again reinforce that it is unexpected that bilinguals should exhibit a disadvantage for controlling interference from environmental noise during auditory comprehension tasks. The present study therefore examined bilingual native language (L1) sentence recognition abilities in conditions with and without noise and compared their performance to monolinguals.

Effect of bilingualism on word recognition in noise

The most commonly employed test to assess bilingual speech perception and word recognition is ‘Speech In Noise’ (henceforth referred to as SPIN) (Bilger, Nuetzel, Rabinowitz, & Rzeczkowski, 1984). This test consists of sentences which have final words of varying predictability. Those with high predictability (e.g., ‘The cabin was made of logs.’) have more contextual cues to how the sentence will end compared to those with low predictability (e.g., ‘I should have known about the gum.’). Participants are asked to identify the last word of a sentence when presented in either a quiet or an acoustically degraded (noisy) condition (e.g., Tabri, Chacra, & Pring, 2011).

Although studies have mostly indicated that bilinguals perform more poorly than monolinguals on word recognition tasks such as SPIN, this disadvantage is primarily exhibited in noisy environments (e.g., Mayo, Florentine, & Buus, 1997; Flege, Munro, & Mackay, 1995; Rogers, Lister, Febo, Besing, & Abrams, 2006). For instance, Rogers et al. (2006) measured monosyllabic word recognition abilities in a group of Spanish-English early bilinguals and English monolinguals in quiet, noisy and reverberated (echoing to mimic a natural environment, e.g. background noise in a café) environments. The bilinguals exhibited significantly lower word recognition scores in conditions with noise and reverberation, but not in the quiet condition. This disadvantage could stem from the additional processing constraints that noise places on speech processing (e.g., Bradlow & Alexander, 2007). Nevertheless, it remains unclear as to why bilinguals should show this disadvantage. However, most studies carry out testing in a second language and with immigrant (late) bilinguals, although Rogers et al. (2006) did use early fluent bilinguals. It is therefore possible that the bilinguals' underperformance in these tasks could be due to their relatively low competency in their second language rather than a disadvantage subsequent to bilingualism.

Age of acquisition effects have indeed been proposed to be a major reason for a bilingual disadvantage in word recognition and better word recognition scores in noise have been reported for early compared to late immigrant bilinguals (e.g., Mayo, Florentine, & Buss, 1997; Meador, Flege, & Mackay, 2000). For instance, Mayo, Florentine and Buss (1997) studied word recognition in acoustically degraded sentences in Spanish-English bilinguals with different age of second language acquisition (bilinguals from infancy, toddler and post-puberty) and English monolinguals using a SPIN task. There was an overall age of acquisition effect with better performance for bilinguals who learned a second language during infancy and as toddlers compared to those who acquired it post-puberty. Nevertheless, overall, the bilinguals obtained poorer word recognition scores than monolinguals regardless of their age of second language acquisition. One could argue that a close phonological similarity between Spanish and English may have contributed to a perceptual confusion in identifying correct phonemes during word recognition. However, a bilingual disadvantage has also been reported for bilinguals who speak phonologically different languages (e.g., Arabic and English; e.g., Tabri, Chacra, & Pring, 2011).

Interestingly, it has been shown that the bilingual disadvantage extends to the native language (L1). For example, von Hapsburg & Bahng (2009) administered a SPIN task (in Korean) to a group of Korean-English late bilinguals with low-to-moderate proficiency in English. It was found that the disadvantage in speech processing in L1 increased in relation to the improvement in proficiency suggesting that the highest level of disadvantage can be observed for bilinguals who have comparatively better proficiency in both languages.

Bradlow and Alexander (2007) suggested that for non-native speakers the locus of disadvantage as a result of noise could be at both segmental (lower level perceptual skills) as well as at syntactic, semantic and pragmatic levels (higher level structural processing). At the phoneme level, they suggest that less exposure to the non-native language makes bilinguals particularly susceptible. In contrast, for native speakers, the adverse effect of noise on phoneme perception may be compensated for by the fully developed phonological system.

To reiterate, few studies have tested word recognition in LI, and those that have generally use a paradigm using SPIN that tests the recognition of only one word at the end of the sentence (e.g., Tabri, Chacra, & Pring, 2011; von Hapsburg & Bahng, 2009). Consequently, in order to further understand the effects of bilingualism beyond the word level, we tested sentence recognition abilities of bilingual and monolingual speakers in quiet and noisy conditions in the speakers' native language (L1). Testing in L1 ensured that the bilingual disadvantages found in previous research were not due to the side effects of differences in proficiency or age of acquisition.

Method

Participants

Twenty bilinguals (mean age = 50. 61, standard deviation = 4.34) and twenty monolinguals (mean age = 52.05, standard deviation = 3.94) participated in the current study. All participants were recruited from the southern Indian state of Kerala. All participants acquired Malayalam as their L1, however the bilinguals were also exposed to, and acquired Tulu (L2) during early childhood (Mean L2 acquisition age = 4.77). Bilingual participants lived in a mixed language environment where L1 was primarily used in the home context and L2 for wider social needs (e.g., communicating with neighbours). Most bilingual and monolingual speakers were self-employed (e.g., running small businesses) or farmers. The bilinguals were highly fluent in their L2, assessed based on a second language proficiency rating scale for speaking (mean = 3.5, standard deviation =.51) and listening (mean = 3.66, standard deviation = .48) [scale ranging from 0 (no proficiency) to 4 (native like)]. The bilingual participants did not acquire literacy skills (reading and writing) in L2 since the language did not have a script and it was not a part of the academic curriculum. Before testing, the participants underwent an audiological evaluation to rule out the possibility of elevated hearing thresholds. Only participants with normal pure tone audiometry thresholds (≤ 15dB) from .25 to 8 kHz for air conduction were tested further.

Materials

Stimuli were twenty sentences in L1 (Malayalam) with 5-6 target words for each sentence (see Appendix 1). The sentences were semantically unpredictable to avoid benefit from contextual information. All the sentences had a similar two adjective+noun+ adverb+ serial verb structure. The sentences described either a physical or mental activity (e.g., “The hungry mother read a nice book.”)

Task & Procedure

In order to degrade the sentences, white noise with a -30dB amplitude compared to signal was added to the sentences using Cubase software (Cubase version 7.07, http://www.steinberg.net/index.php?id=downloads_cubase_7&L=1). Degradation was carried out with a signal sampling rate of 44100 Hz, in monoformat with 16 bits using a third order low pass filter with a cut off of .3db at 250 Hz and -18 db per octave roll off beyond 250 Hz. Both acoustically degraded and non-degraded sentences were recorded on a Windows PC. The output (intensity) level for sentence presentation was established at an average 50 dB for both types of sentences. This was established after presenting the non-degraded sentences to a group of 5 participants in order to obtain an average comfort level.

The testing was carried out in a soundproof room. Every participant heard every sentence in both conditions, in different random orders. Sentences were presented in the acoustically degraded condition first. Participants heard the sentences dichotically through the headphones. The experimenter controlled the onset of each stimulus. After the presentation of acoustically degraded sentences, each participant had a 2 minute break before the non-degraded sentences were presented repeatedly. The duration of each target sentence presentation was approximately 5 seconds and the gap between the target sentences was 15 seconds. The participants were instructed to pay attention to each sentence carefully. At the end of each target presentation, the participants were asked to repeat the entire sentence immediately. The total duration of sentence presentation and repetition was 10 minutes. Responses were audio-recorded and phonetically transcribed using the International Phonetic Alphabet (IPA) for later analysis.

Analysis

The responses of both language groups were analysed based on repetition accuracy scores for conditions with and without noise degradation. If the sentences were produced with 100 percentage accuracy (all words in sentence accurately), a score of 1 was given. A score of 0 was given for sentences with errors (e.g., omission, repetition, substitution of phonemes or words). The sentence accuracy data was analysed using a 2 (speaker group: monolingual vs. bilingual) × 2 (condition: acoustically degraded vs. non-degraded) repeated measures Analysis of Variance.

Results

As expected, there was a significant main effect of condition ($F(1, 19) = 17.09$, $p = .001$, $\eta^2_p = .474$) with comparatively more accurate repetition scores when the sentences were presented in the quiet condition than when acoustically degraded with noise (see Figure 1).

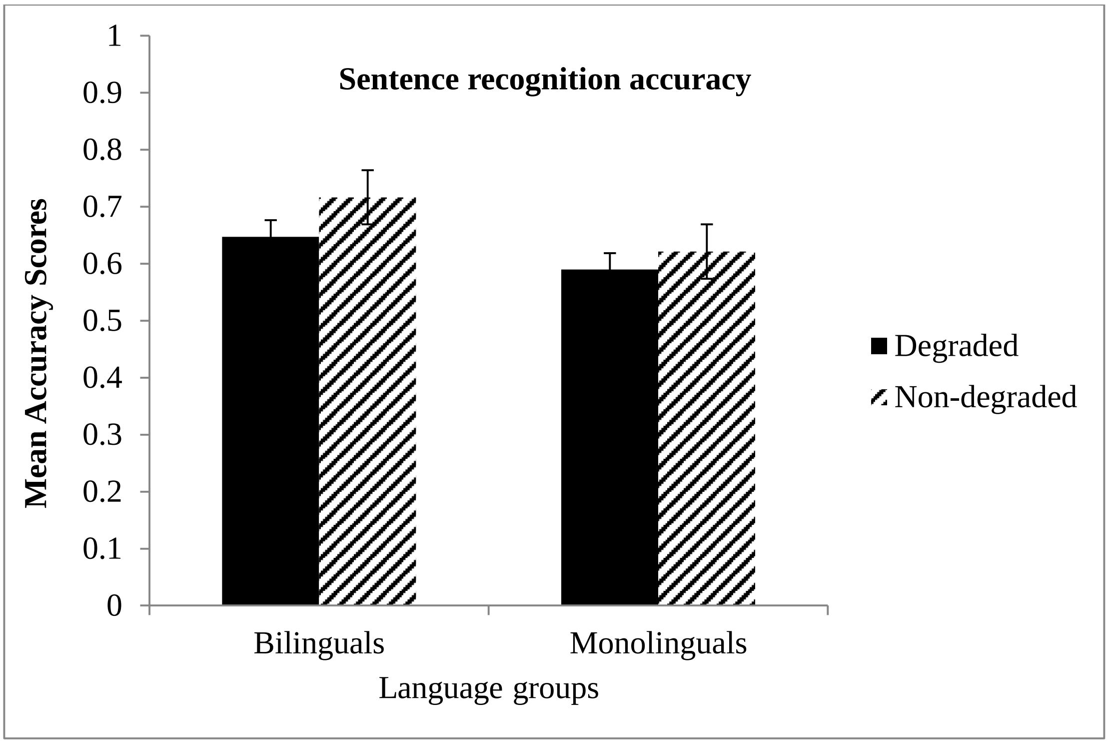

Figure 1. Mean sentence accuracy for two conditions (degraded vs. non-degraded) for two language groups. Error bars represent Standard Error.

Although bilinguals showed a trend to being more accurate (monolinguals: M= .62, SE=.03, 95% C1: [.54, .68]; bilinguals: M=.67 SE=.03, 95% C1: [.60, .74) this was not significant ($F(1, 19) = 2.53$, $p = .128$, $\eta^2_p = .117$). There was also no significant interaction between the condition and language group ($F(1, 19) = .842$, $p = .370$, $\eta^2 = .042$,).

Discussion

The present study compared word recognition abilities in bilinguals and monolinguals in acoustically degraded and non-degraded conditions in their native language to investigate whether the word recognition system in bilinguals has been disadvantaged by the speaker's bilingual status as had been found in the previous literature. The results showed no significant difference between bilinguals and monolinguals in their accuracy, or any interaction across the acoustically degraded condition with noise and the non-degraded condition without noise. Indeed, if anything, bilinguals showed a trend to being more accurate than the monolinguals. Therefore, our results are incompatible with previous studies, which had found a word recognition cost associated with bilingualism for stimuli that were acoustically degraded with noise (Meador, Flege, & Mackay, 2000; Mayo, Florentine, & Buss, 1997; Neuman, Wroblewski, Hajicek, & Rubinstein, 2010). Nevertheless, they are in line with previous studies that found similar performance between bilinguals and monolinguals in non-degraded quiet conditions (e.g., Rogers et al., 2006).

What factors may have influenced our results' divergence from the literature. One prominent factor is proficiency: Most studies have measured word recognition abilities in L2. As noted above, age of acquisition has been found to influence the size of the perceptual decrement (Mayo, Florentine, & Buss, 1997). This issue gets more complicated when L2 status is strongly associated with immigration and classroom learning. Although proficiency is controlled in most of the studies, it is possible that poor word recognition skills may reflects difficulty of perceiving accent or specific phonological features, and especially for immigrant bilinguals. It is therefore possible that this perceptual difficulty may have been misattributed to a word recognition disadvantage associated with bilingualism. However, in our study, not only had the bilingual speakers acquired their L2 early and were highly proficient, but they were also tested in their L1.

Why might our results differ from studies suggesting a bilingual disadvantage for recognizing words even in L1 (Tabri, Chacra, & Pring, 2011). It is possible that the nature of the task may play a role. For example, most studies use the SPIN (Sentence Processing In Noise) test to examine word recognition. However, this requires only repeating (or writing) one target word at the end of each sentence presentation. Recently, Filippi, Leech, Thomas, Green and Dick (2012) argued that this method is not a suitable paradigm to understand whether bilinguals suffers from a disadvantage under conditions with linguistic interference. It is also likely that using non-linguistic distractors such as noise may not provide full understanding about bilingual word recognition abilities in natural environment. In contrast, our paradigm required the participants to repeat the entire sentence. This would seem a more natural task for participants that closer resemble everyday conversation. Moreover, other studies have shown bilingual advantages in the auditory domain for suppressing non-target competing (distractor) words during comprehension (Blumenfeld & Marian, 2011). This suggests that a bilingual advantage may be evident for only tasks involving linguistic (competing words) but not non-linguistic interference (noise) affecting speech processing skills.

One might suppose that this sentence processing task should be easier for monolinguals since their language system does not need to suppress competing distractors from the non-target language. In contrast, bilinguals are faced with two types of interference – interference from noise and from their competing lexicons. In order for performance to be equivalent to that of monolinguals, we suggest that the highly specialised task schema may be able to handle both types of interference as implemented, for example in models of bilingual inhibitory control (e.g. Abutalebi & Green, 2007; Dijkstra & Van Heuven, 2002; Green, 1998). The Supervisory Attentional System in the inhibitory model is specialised in reducing interference and selecting the right lexical item, and we suggest that the lack of a disadvantage for bilingual speakers reflects the efficient operation of this system.

In sum, the results of the present study found no evidence for a bilingual disadvantage even when the bilingual participants were exposed to acoustically degraded sentences. We suggest that in bilinguals, efficient control mechanisms for both comprehension and production in bilinguals may compensate for difficulties originating at the level of speech processing due to noise. Furthermore, previous claims of a bilingual disadvantage for word recognition may be best explained by differences in proficiency, effect of task type and other perceptual difficulties in L2.

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Appendix 1

Sentence stimuli in IPA with English translations and Malayalam Script

1. praɕasṯana:ja aḏʰja:pakan maɻajil n̪an̪aɲ:u kuɭiʧ͡ʧu
2. The famous teacher got drenched in the rain.
3. പ്രശസ്തനയ അധ്യാപകൻ മഴയിൽ നനഞ്ഞു കുളിച്ചു

1. viɕan:u valaɲ:a amma pusṯakam va:jiʧu rasiʧ:u
2. The hungry mother read and enjoyed a book.
3. വിശന്നു വലഞ്ഞ അമ്മ പുസ്തകം വായിച്ചു രസിച്ചു

1. sun̪d̪arija:ja pe:ŋkuʈʈi ʧeɭijil iraŋ:i kaɭiʧu
2. The beautiful girl got into the mud and played.
3. സുന്ദരിയായ പെണ്കുട്ടി ചെളിയിൽ ഇറങ്ങി കളിച്ചു

1. vṛdd̪ʰaja:ja mut̪:aɕi uʧ:at̪:il pa:ʈ:u pa:di
2. The old grandmother sang a song loudly.
3. വൃദ്ധയായ മുത്തശി ഉച്ചത്തിൽ പാട്ടു പാടി

1. ɕakt̪na:ja ve:ʈ:ak:a:ran kuɖat̪:il veɭ:am niraʧu
2. The strong hunter filled water in the pot
3. ശക്തനായ വേട്ടക്കാരൻ കുടത്തിൽ വെള്ളം നിറച്ചു

1. . a:ro:gjavat̪ija:ja st̪ri: paʈ:am parat̪:i nadan:u
2. The healthy woman wandered around flying kites
3. ആരോഗ്യവതിയായ സ്ത്രീ പട്ടം പറത്തി നടന്നു

1. t̪adijana:ja pu:ʤa:ri ka:ʈ:il ʧut:i nadannu
2. The fat priest roamed around in the forest
3. തടിയനായ പൂജാരി കാട്ടിൽ ചുറ്റി നടന്നു

1. bud̪d̪ʰima:na:ja karʂkan pu:k:al manat̪:u nadan:u
2. The intelligent farmer walked around smelling flowers.
3. ബുദ്ധിമാനായ കർഷകൻ പൂക്കൾ മണത്തു നടന്നു

1. dɛ:ʂjak:a:rana:ja aʧʧʰan vi:du kaɻuki vṛit̪:ija:k:i
2. The angry father washed the house clean.

3. ദേഷ്യക്കാരനായ അച്ഛൻ വീട് കഴുകി വൃത്തിയാക്കി

1. d̪ʱan̪ikana:ja katʃtʃʰavaʈakːa:ran marat̪ːil kajar̥i irun̪ːu
2. The wealthy merchant climbed and sat on a tree.
3. ധനികനായ കച്ചവടക്കാരൻ മരത്തിൽ കയറി ഇരുന്നു

1. sand̪o:ʂavat̪ija:ja ve:lakːa:ri pust̪akam edut̪ːeriɲːu
2. The happy servant took the book and threw it.
3. സന്തോഷവതിയായ വേലക്കാരി പുസ്തകം എടുത്തെറിഞ്ഞു

1. d̪a:hitʃːu valaɲa kaḷːan nilaviɭakːu koɭut̪ːi vetʃu
2. The thirsty robber lit a lamp.
3. ദാഹിച്ചു വലഞ്ഞ കള്ളൻ നിലവിളക്ക് കൊളുത്തി വെച്ചു

1. 13. midukːan̪a:ja kuʈːi kase:ra oditʃu kaɭaɲːu
2. The intelligent boy broke a chair
3. മിടുക്കനായ കുട്ടി കസേര ഓടിച്ചു കളഞ്ഞു

1. . ro:gija:ja mukːuvan kuɭat̪ːiɭe:kːu edut̪ːu tʃa:di
2. The sick fisherman jumped into the pond
3. രോഗിയായ മുക്കുവാൻ കുളത്തിലേക്ക് എടുത്തു ചാടി

1. pa:vapːeʈːa juva:v kapːalil kajari saɲtʃaritʃːu
2. The poor boy travelled in a ship
3. പാവപെട്ട യുവാവ് കപ്പലിൽ കയറി സഞ്ചരിച്ചു

1. n̪i:ɭamuɭːa po:li:suka:ran kaʈːilil kidan̪ːur̥aŋːi
2. The tall policeman slept on a cot
3. നീളമുള്ള പോലീസുകാരൻ കട്ടിലിൽ കിടന്നുറങ്ങി

1. viʂamitʃːu nin̪ːa pe:ɳkuʈːi put̪ija vast̪ram va:ŋːi
2. The sad girl bought a pair of new dress
3. വിഷമിച്ചു നിന്ന പെണ്കുട്ടി പുതിയ വസ്ത്രം വാങ്ങി

1. an̪d̪^{h}an̪a:ja do:kʈar pu:kːaɭ paɾ̥itʃːu kaɭaɲːu
2. The blind doctor plucked and threw away the flowers
3. അന്ധനായ ഡോക്ടർ പൂക്കൾ പറിച്ചു കളഞ്ഞു

1. vikṛit̪ija:ja a:ɳkuʈːi pust̪akam va:jitʃu paʈ^{h}itʃːu
2. The naughty boy read and learned a book
3. വികൃതിയായ ആണ്കുട്ടി പുസ്തകം വായിച്ചു പഠിച്ചു

1. kru:ran̪a:ja ka:valkːa:ran basːil kajaɾ̥i irun̪ːu
2. The cruel watchman climbed and sat in a bus.
3. ക്രൂരനായ കാവൽക്കാരൻ ബസിൽ കയറി ഇരുന്നു

Chapter 4

Consequences of late bilingualism for novel word learning: Evidence from Tamil-English bilingual speakers.

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Abstract

Aims and objectives: Recent studies that have investigated novel word learning have demonstrated an advantage for bilinguals compared to monolinguals (e.g., Kaushanskaya & Marian, 2009b). The study reported here sought to explore whether a word learning advantage is revealed only for early bilinguals with comparable proficiency in both their languages, or whether such advantages are also observed in individuals with relatively late experience of, and less proficiency in, a second language.

Methodology: We tested the acquisition of novel words in an unknown language using identification and naming tasks in three groups of 20 participants; monolingual Tamil speakers, 'early' Tamil-English bilingual speakers, and late Tamil-English bilingual speakers.

Data and Analysis: The data were analysed using a non-parametric Kruskal-Wallis test followed by linear regressions.

Findings: The results showed a bilingual advantage for word learning as evidenced by superior performance in both the naming and identification tasks and, critically, late bilinguals outperformed monolinguals.

Originality: The results of the present study revealed, for the first time, a bilingual advantage in word learning even when individuals acquire their second language later in life.

Significance: The results suggest that the positive effects of bilingualism may generalize beyond non-linguistic tasks, perhaps affecting a general language learning mechanism. Moreover, this seems to occur even in late bilingualism. This is in contrast to the reported effects on cognitive control mechanisms that show only weaker advantages for individuals who learned a second language later in life.

Introduction

One of the most significant findings to have emerged from research examining bilingualism and cognitive processing is that bilingual children and older adults perform particularly well in tasks involving cognitive processing skills such as selective attention and inhibitory control (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006; Costa, Hernandez, & Sebastián-Gallés, 2008). Similarly, studies that have investigated the effect of bilingualism on language learning suggest that an early bilingual experience leads to an advantage in novel word learning (e.g., Bartlotti & Marian, 2012; Bartlotti, Marian, Schroeder, & Shook, 2011; Grey, 2013; Kaushanskaya, 2012; Kaushanskaya & Marian, 2009a, 2009b, Van Hell & Mahn, 1997, Wang & Saffran, 2014; Yoshida, Tran, Bentitez, & Kuwabara, 2011).

Although the advantages of bilingualism for cognitive processing and language learning are well established, the precise nature of the bilingual experience that is needed to obtain a bilingual advantage is not fully understood. For example, the majority of the studies that have reported a bilingual advantage have examined cognitive processing and language learning advantages in early bilinguals with comparable speaking proficiency in both languages. However, bilingual experience can vary in a number of ways. For example, individuals can have varying levels of second language proficiency due to the nature and length of language exposure (high and low proficiency bilinguals). They may also have different age of acquisition depending on whether the second language was learned in early or late childhood (early and late bilinguals) and/or distinct patterns of language acquisition (simultaneous and successive bilinguals). Each of these aspects of bilingual experience may interact with bilingual cognitive-linguistic abilities distinctively, yet an understanding of the influence of each of these unique but varied experiences on bilingual cognitive processing or language learning is limited. Although some studies have started to examine the impact of age of second language acquisition on cognitive processing (e.g., Tao, Marzecova, Taft, Asanowicz, & Wodniecka, 2011), the effects on bilingual language learning abilities are relatively less studied. The purpose of the present study was to examine how the experience of late acquisition of a second language impacts novel word learning ability in bilinguals and to compare their performance with monolinguals and relatively more proficient early bilinguals.

The bilingual advantage in novel word learning

It has been suggested that a general bilingual advantage for novel word learning is possible in speakers who are early bilinguals. For example, Kaushanskaya and Marian (2009b) examined whether there was a bilingual advantage for novel word learning for early bilinguals, and also investigated how experience with phonologically and orthographically similar or dissimilar languages influenced performance. Previous studies (e.g., Bialystok, Majumder, & Martin, 2003) had indicated that individuals, who are exposed to languages that are phonologically and orthographically similar (e.g. Spanish-English) may show a bilingual advantage in phonological awareness tasks. For example, Bialystok et al. (2003) found a phonological awareness advantage for bilingual children who were exposed to phonologically and orthographically similar languages but that this bilingual advantage was not found for languages with different scripts (e.g. Chinese and English). Kaushanskaya and Marian (2009b) argued that if exposure to phonologically similar languages can influence phonological awareness, the same effect may be found for novel word learning. They suggested that parallels could be drawn between phonological awareness and novel word learning since both involve phonological processing.

Their adult, early bilingual, participants were native speakers of English and had acquired either Spanish or Mandarin as their second language primarily in a family context. English-Spanish bilinguals (phonologically/orthographically similar languages), English-Mandarin bilinguals (phonologically/orthographically distinct languages) and English monolinguals learned 48 non-words and their English translations. In contrast to predictions, immediate and delayed retention of English translations failed to reveal any learning difference between the two groups of bilinguals. Nevertheless, both groups of bilinguals' demonstrated superior word learning performance compared to monolinguals. While the results have been taken as evidence for a word learning advantage in bilinguals, it is unclear if the translation task used in this study can be taken as a direct measure of word learning. Translation skills form an essential component of a bilingual experience (e.g., Malakoff, 1992) therefore; the observed advantage could reflect the better performance of bilinguals on translation tasks rather than any advantage in learning of novel words. Papagno and Vallar (1995) found a word learning advantage for multilinguals compared to bilinguals, measured using a paired associate word learning task. A number of cognitive-linguistic measures including verbal memory, vocabulary knowledge visuo-spatial span visuo-spatial memory were tested to examine whether differences in phonological memory could account for any word learning advantage demonstrated by multilinguals compared to bilinguals. The results indicated that multilinguals were significantly better at word learning than bilinguals and also showed better auditory digit span and non-word repetition scores, two critical measures of phonological memory. The authors therefore suggested superior phonological memory to be a potential contributor to the better word learning abilities of multilinguals compared to bilinguals. However, correlation does not necessarily mean causation: Though an association between multilingualism, superior word learning and superior phonological memory was evident in the study, it is possible that the multilingual participants already possessed a better phonological memory leading to the acquisition of multiple languages. More recently, Kaushanskaya (2012) provided further evidence of a role for phonological memory in the bilingual word learning advantage. She examined novel word learning in a group of English-Spanish early bilinguals and English monolinguals. Monolingual speakers were divided into high and low memory span groups based on their performance on a forward digit span task.

The digit span performance of high span monolinguals was equal to that of the bilinguals. Participants were exposed to novel words that were either similar to English phonology (familiar) or dissimilar to English phonology (unfamiliar) and their English translations. Results indicated that bilinguals outperformed both high and low memory span monolinguals and did not show any differences in learning between novel words with familiar phonology and those with unfamiliar phonology. Interestingly, however, depending on their memory span monolinguals exhibited differences in learning of phonologically unfamiliar novel words (but not phonologically familiar novel words): high memory span monolinguals learned phonologically unfamiliar novel words better than low memory span monolinguals. These findings show that, while differences in phonological memory may contribute to novel word learning ability in monolinguals, they cannot fully account for the bilingual advantage in this task. Although this study replicated a bilingual advantage in novel word learning, once again, learning was tested using a translation task which makes it difficult to discern whether the observed advantages were a direct result of differences in learning ability.

In a different set of experiments Kaushanskaya and Rechtzigel (2012) examined whether the bilingual advantage in novel word learning varied depending on whether words were concrete or abstract. Their manipulation was based on previous evidence suggesting a learning advantage for concrete words than abstract words due their robust lexical-semantic representations (e.g., De Groot & Keijzer, 2000). They suggested that the effect of concreteness might be larger for bilinguals for two reasons a) the bilingual ability to learn novel words may be partially rooted in their ability to better encode semantic information. This might lead to an advantage in learning words that contain rich semantic information; b) concrete words might activate semantic information in both languages for bilinguals compared to monolinguals. The authors predicted that this wider activation of semantic information would therefore facilitate acquisition of concrete words more than abstract words. English-Spanish late bilinguals and English monolinguals learned concrete and abstract novel words through a translation task. Reaction time data failed to show any significant difference in performance between two groups however accuracy data revealed an overall benefit of concreteness for both bilinguals and monolinguals. Furthermore bilinguals showed a larger (almost double) effect of concreteness compared to monolinguals, suggesting a greater bilingual sensitivity to semantic information during novel word learning.

Kaushanskaya, Yoo and Van Hecke (2013) investigated whether acquisition of novel words in bilinguals was constrained by the phonological properties of novel words. The authors also examined how degree of second language experience interacted with novel word learning. Native speakers of English with varying level of Spanish second language knowledge (experienced and inexperienced) were tested using a forced choice recognition task for the acquisition of phonologically familiar and unfamiliar novel words paired with either a known (animal) or unknown referent (alien). Both groups of participants showed an effect of phonological familiarity that was significant only when the novel words were paired with a familiar referent. Experienced second language learners also only outperformed inexperienced learner, under the same conditions (when unfamiliar novel words were paired with a familiar referent). These findings indicate that increased second language experience affects word learning however such effects in bilinguals may be modulated by whether the referent with which the novel word is paired already has a word referent in the participants vocabulary (ie animals vs. aliens). It has also been shown that a bilingual advantage in novel word learning varies relative to the task demands. For example, Kan and Sadagopan (2014) found no difference in the performance between monolingual and bilingual young adults on novel word retention abilities when measured through either comprehension or naming probes. However a previous study conducted by Kan, Sadagopan, Janich and Andrade (2013) did find a specific bilingual advantage for comprehension scores, although still not for word production.

Evidence also suggests a distinct neural activation pattern for word learning in bilinguals and monolinguals. For example, Bradley, King and Hernandez (2013) gave novels words in German to Spanish-English bilinguals and English monolinguals to identify whether cognitive control mechanism responsible for novel word learning in bilinguals and monolinguals differed. Although their word accuracy did not suggest any significant difference between monolinguals and bilinguals the reactions time data indicated an overall faster reaction time for bilinguals. Critically, the neuroimaging data revealed that the bilingual brain activation was constrained to specific regions (e.g., putamen). In contrast, the results indicated that monolinguals had a wider activation of brain regions. The authors concluded that a wider activation of brain regions is associated with slower reaction times and this may explain the increased monolingual difficulties in retrieving learned novel words during learning.

Bilingual advantage in late bilinguals

To the best of our knowledge, there is only one study that has explicitly probed the effect of age of acquisition of a second language on novel word learning in bilinguals: Kaushanskaya and Marian (2007) compared monolinguals with high proficiency early bilinguals (second language acquisition around 3 years of age) and high proficiency late bilinguals (around 12 years). Participants heard 48 non-words and saw their English translations. During production and identification probes, participants heard a non-word, and were required to produce the associated English translations and then selected the correct English translation from a choice of five. Superior learning performance was observed in early bilinguals compared to monolinguals indicating a bilingual advantage for novel word learning. However, despite having comparable second language proficiency to the early bilinguals, the late bilinguals did not demonstrate a significant advantage over monolinguals.

This prompted the authors to suggest that the bilingual advantage in novel word learning was sensitive to age of acquisition.

The present study

The findings from a small number of studies in the literature confirm a bilingual advantage for word learning. However, it is not clear whether such an advantage is only seen for individuals with extensive knowledge of many languages (Papagno & Vallar, 1995) or in cases of early bilinguals (Kaushanskaya, 2012; Kaushanskaya & Marian, 2009b). The effect of bilingualism on novel learning has been insufficiently investigated, with the exception being Kaushanskaya and Marian (2007), and much remains to be explored, particularly regarding novel word learning in late bilingual individuals with limited second language proficiency.

The present study focuses on the impact of late language experience on novel word learning. One of the key learning demands for a late second language learner is to master many novel words. Therefore, it is possible that this experience positively affects the word learning mechanism leading to a bilingual advantage. Alternatively, it is possible that for late bilinguals, the language learning system is relatively less amenable to positive effects of additional experience (unlike that of early bilinguals) resulting in no bilingual advantage. To investigate these possibilities, we examined novel word learning performance in late bilinguals with low second language proficiency and compared their performance to monolinguals and proficient bilinguals who acquired their second language earlier.

In contrast to the majority of previous studies, which have used translation tasks, (Kaushanskaya & Marian, 2007, 2009b, 2012) we used a novel word learning task which probed learning through a picture naming and identification task. If bilingual experience results in a novel word learning advantage, we predicted that even a late bilingual experience may affect the language learning mechanism which may then facilitate foreign vocabulary acquisition. This predicts that late bilinguals should perform better than monolinguals and possibly even comparably to early bilinguals in learning.

Method

Participants

The participants were 60 adults in three age-matched groups: 20 Tamil monolinguals and 40 Tamil-English bilinguals in two groups of 20 (see below for further details). Background data for the participant groups are given in Table 1. The monolinguals (11 males and 9 females) received their education from the local government schools that promoted native language literacy instruction. None of the monolingual participants reported any exposure to English or to any other language at home or in their work environment.

The bilingual participants rated their language competence across four language modalities (speaking, understanding, reading, writing) on a scale ranging from 0 (not proficient) to 4 (highly proficient) based on the Chengappa, Shivashankar, Nair, Nayak and Arvind (2011) test of language proficiency. The bilingual participants were divided into two groups (Table 1) based on their age of second language (L2) acquisition for speaking and language proficiency: One group we label 'early' bilinguals (with high proficiency) and the second 'late' bilinguals (with low proficiency). The mean age of onset of speaking in L2 was the primary measure as it generally indicates the start of active bilingualism (Luk, De Sa, & Bialysok, 2011).

The 'early' bilinguals (13 males and 7 females) were native speakers of Tamil (L1) and acquired English (L2) as a second language. Sixteen of these participants reported that their initial exposure to L2 was in a formal and educational setting and the remaining four participants were exposed to L2 (reading and writing) informally in a family context prior to their schooling. For all 'early' bilingual participants, their schooling was entirely in English (high exposure). Our definition of 'early' bilinguals was based on being exposed to L2 by the age of 5 (earlier than late bilinguals), onset of fluent speaking by 9 years and being immersed in an English speaking environment during schooling. For our ‘early’ bilingual participants the mean onset age of L2 introduction (for reading and writing) was 4.7 years (SD = 0.46; maximum age = 5.0) and for fluent speaking was 8.3years (SD = 0.44, maximum age = 9.0).

Late bilinguals (11 males and 9 females) had a delayed onset of introduction to L2. L2 was introduced to them as a restricted part of the school curriculum in an English language lesson primarily through reading and writing (mean onset age = 6.2, SD = 0.84; minimum age = 6.0) with a mean onset age for fluent speaking of 12.45 years (SD = 0.73, minimum age = 12.0). The late bilinguals reported that the delayed onset age for speaking in their L2 had resulted in lesser competence in L2 compared to L1. The late bilinguals were disadvantaged as their exposure to L2 was restricted (low exposure) and therefore L2 acquisition was slow and limited. Late bilinguals and ‘early’ bilinguals differed significantly in both age of onset of bilingualism measured by speaking and rated proficiency in all language modalities (see Table 1). Although our ‘early’ bilinguals became fluent in their L2 four years earlier than our late bilinguals, they still acquired their L2 relatively late. Nevertheless, we wished to examine whether even with this, perhaps weak, division, there would be a significant difference between the groups in their word learning.

Linguistic context of the participants

The bilingual and monolingual participants were all from Coimbatore, a town located in Tamil Nadu, a Southern Indian state. Tamil is the most widely used spoken language by the local population. English is mainly taught in schools as a second language to meet educational needs. Although Hindi is one of the 22 official languages of the Indian subcontinent, it is not used as a medium of communication in major parts of Southern India. In Tamil Nadu, Hindi is extremely unpopular, and rarely encountered, as a medium of communication or as a language of popular culture for historic and political reasons (see Forrester, 1966; Pandian, 1996 for detail on this topic). The participants in the current study reported no prior exposure to this language.

Participant demographics and background measures

The participants completed a non-word repetition task as a measure of phonological short-term memory. Previous studies have indicated that phonological short-term memory can influence word learning (e.g., Gupta, 2003). Non-word repetition is one of the most widely used methods to assess phonological short-term memory. In this task, participants were presented with ten non-words within the range of 2-8 syllables that had the phonology of Tamil. Each non-word was presented separately with increasing syllable length via headphones. The participant's task was to repeat the single presented non-word. A score of 1 was given for each correct response with no production errors.

As shown in Table 1, univariate ANOVA showed a significant effect of group on nonword repetition performance [$F (2, 38) = 3.67$, $p = .035$, $\eta^2=.22$]. Bonferroni adjusted significance tests for pairwise comparisons revealed that monolinguals showed significantly poorer nonword repetition compared to 'early' bilinguals (mean difference = -.75, 95% CI: [-1.45, -.04], $p = .034$). However, there were no significant differences between late bilinguals and either monolinguals (mean difference = -.25, 95% CI: [-.45, .95], $p = .252$) or 'early' bilinguals (mean difference = -.50, 95% CI: [-1.20, .20], $p = .252$). Socio-economic status (SES) of the participants was assessed based on four critical indicators (pooled monthly income, highest education, and occupation and family properties) by socio economic status scale (Venkatesan, 2011). There was a significant difference in SES between all three groups: [$F (2, 57) = 298.57$, $p < .001$, $\eta^2=.91$]. Bonferroni adjusted significance tests for pairwise comparisons revealed significantly lower SES scores for monolinguals compared to 'early' bilinguals (mean difference = -4.25, 95% CI: [-5.175, -3.32], $p < .001$) and late bilinguals [mean difference = -4., 95% CI: [-5.87, -4.02, $p < .001$]. Late bilinguals also showed significantly lower SES scores compared to 'early' bilinguals (mean difference = 9.20, 95% CI: [-8.27, 10.12, $p < .001$]. The implications of these results are discussed further below.

Table 1. Demographic and background data of participants as means and standard deviations (in parentheses).

Demographic data	Mono	LateBi	EarlyBi	p
Age (years)	22. 7 (1.45)	22. 1 (2.02)	21. 6 (1.68)	.328
Socio economic status[a]	5.04 (0.21)	9.28 (0.82)	14.23 (1.77)	< .001
Non-word repetition[b] (n=10)	6.80 (0.81)	7.05 (.66)	7.55 (1.02)	.035
L2 acquisition age (speaking)	-	12.45 (0.73)	8.3 (0.44)	< .001
Proficiency ratings[c]				
Speaking	-	2.42 (0.49)	3.15 (0.36)	< .001
Listening	-	2.57 (0.49)	3.68 (0.46)	< .001
Reading	-	2.52 (0.51)	3.55 (0. 51)	< .001
Writing	-	1.93 (0.30)	3.42 (0.50)	< .001

Notes
N = 20 for all three participant groups
Mono:Monolinguals, LateBi:Late Bilinguals, EarlyBi:'Early' Bilinguals
p = significance of univariate ANOVA between three language groups for age, nonword repetition and SES and significance of t-test (2 tailed) for proficiency ratings between late and 'early' bilinguals.
[a]Scale from 0 (lowest SES) to 20 (highest SES). Pairwise group performance for SES are reported above
[b]The pairwise group performance for non-word repetition are reported above.
[c]Ratings from 0 = not proficient to 4 = highly proficient

Stimuli

The novel word stimuli and pictures (see Appendix 1) were selected from the Hindi picture word articulation test (Kacker, Basavaraj, Thapar, Menon, & Vasudeva, 1990). The test consists of 68 coloured photographs of objects with disyllabic Hindi names for assessing the production of 48 speech sounds in the initial, medial and final position. For the purpose of the present study, we selected ten target words as learning stimuli. The target words selected were all common nouns with no close word similarity to Tamil or English. The ratings for word similarity for both the languages were carried out by 5 Tamil-English bilingual speech pathologists based on a 1-4 point rating scale (1 = no resemblance with Tamil or English, 4 = close resemblance with Tamil or English). Ratings indicated that the novel words did not show any close resemblance to either Tamil (M = 1.06, SD = 0.25) or English (M = 1.13, SD = 0.32). The novel words did not contain any non-native phonemes of Tamil. Each novel word was paired with a picture corresponding to its Hindi referent. The learning stimuli were audio recorded by a fluent speaker of Hindi. Audio files of all stimuli were recorded by a native Hindi speaker and presented in combination with the pictures using Powerpoint.

Procedure

Before the familiarisation and learning phase began, the participants filled in a language proficiency questionnaire and performed the background testing. The participants then sat in front of a computer (Compaq Presario V6425TU laptop) in a soundproof room. The entire session (background, familiarisation, learning and test) lasted for two hours.

Familiarisation phase

The session started with a familiarisation phase, where participants were each presented with each target word and its corresponding picture once. The familiarisation phase included an introduction to the learning session (see instructions below), learning phase and an opportunity to ask questions. In the introduction they were instructed: “You will hear some words from another language that is unknown to you. You must pay keen attention to these words and their corresponding pictures. It is important to listen to all the words correctly because your ability to remember these words will be tested immediately after the learning.”

The participants were told about the entire task and were made aware that repetition of a word or an entire learning session was not possible. After the introduction participants were asked to carefully listen to each novel word presented auditorily through headphones and simultaneously look at the picture of the referent that was displayed on the computer monitor.

At the end of familiarisation phase, participants were encouraged to ask questions regarding the task and were provided with answers before the start of the learning phase. The approximate duration of this phase was 20-30 minutes.

Learning phase

In the learning phase, all the novel word stimuli were presented repeatedly three times in random order. The stimuli were randomised individually for each participant. Each presentation consisted of hearing the auditory stimulus and seeing its visual referent. The word and picture appeared simultaneously and the picture remained on the computer screen for around 30 seconds. The duration of picture presentation was constant across participants for all learning sessions. The participants sat silently during stimulus presentation. At the end of the third presentation, in order to enhance the effect of learning, participants performed a repetition phase: after listening to each target word on headphones they repeated the novel words aloud three times (no pictures were presented). The approximate duration of each learning session was 5 minutes, with the final session taking approximately 8-10 minutes due to the repetition component.

Test phase

At the end of the learning phase, the acquisition of these novel words was assessed using picture naming and identification tasks.

In the picture naming task, the participant was asked to name the picture of the target referent using the newly learned Hindi word. Responses were audio-recorded and phonetically transcribed using the International Phonetic Alphabet (IPA) for later analysis.

In the identification task, a set of three picture choices were provided. The picture choices included the target referent and two semantically unrelated distractors from the stimulus set (none of the words were repeated more than 3 times). The target word was then presented auditorily and the participant was instructed to point to the picture that corresponded to the auditory stimulus. For both naming and identification a maximum response time of one minute was provided. However, if the responses were obtained before one minute then the next target word was presented. Testing lasted for approximately 15-20 minutes.

Analysis

Responses were analysed based on the identification and naming accuracy scores for all the three groups (monolinguals, late bilinguals and 'early' bilinguals). Naming responses were classified as correct when the participant produced the novel word with 100% accuracy. Words with production errors (e.g., omission, repetition, substitution of phonemes, naming a wrong word from the target items) were considered as incorrect responses.

Results

Participants' naming and identification accuracy are given in Figures 1 and 2. For both tasks, as there was a ceiling effect in the data (for 'early' bilinguals) we therefore used a non-parametric Kruskal-Wallis test to examine the effects of group (monolingual, late bilingual, 'early' bilingual) on performance followed by planned pairwise comparisons.

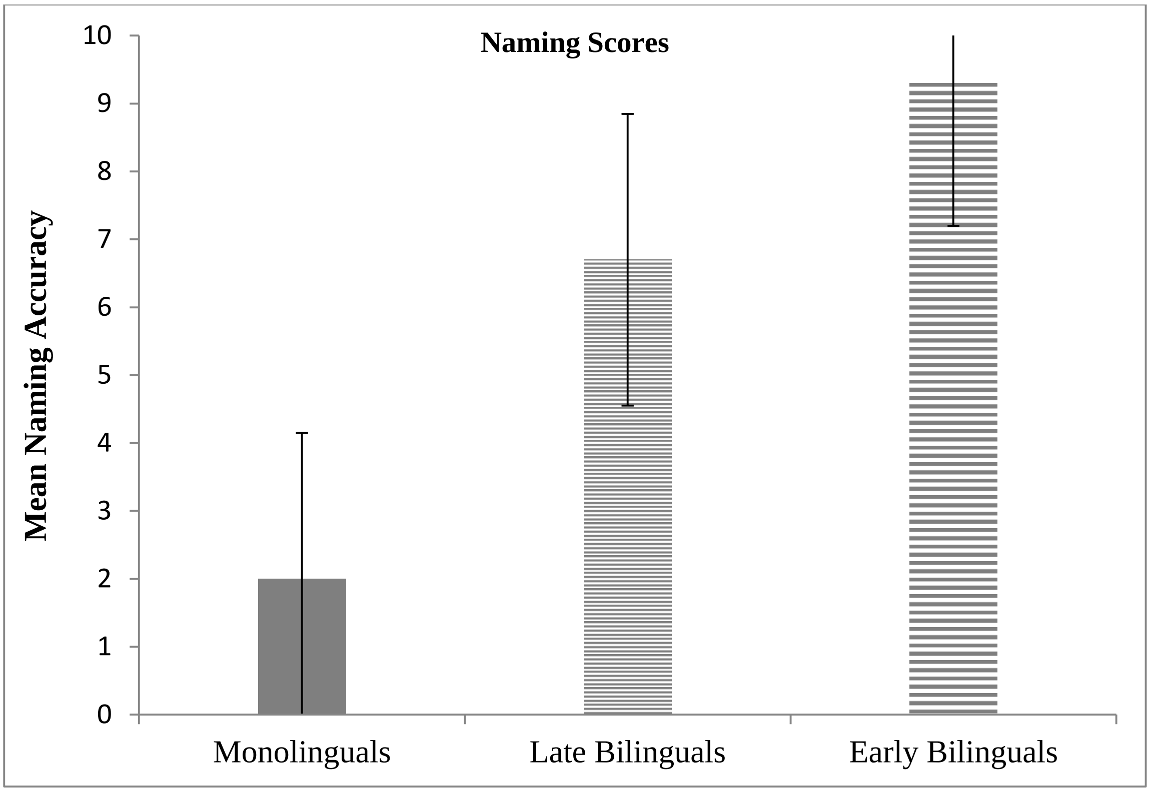

Figure 1. Participants' mean naming accuracy (maximum score =10), Error bars = Standard Error.

There was a significant difference in naming accuracy across the groups (Kruskal Wallis: χ^2 (2) = 49.38, $p < .001$). Bonferroni adjusted significance tests for pairwise comparisons revealed a significant difference for naming scores between all the groups (monolinguals (mean rank = 10.55) and late bilinguals (mean rank = 32.00), $p < .001$, monolinguals (mean rank = 10.55) and 'early' bilinguals (mean rank = 48.95), $p < .001$ and between late (mean rank = 32.00) and 'early' bilinguals (mean rank = 48.95), $p < .001$).

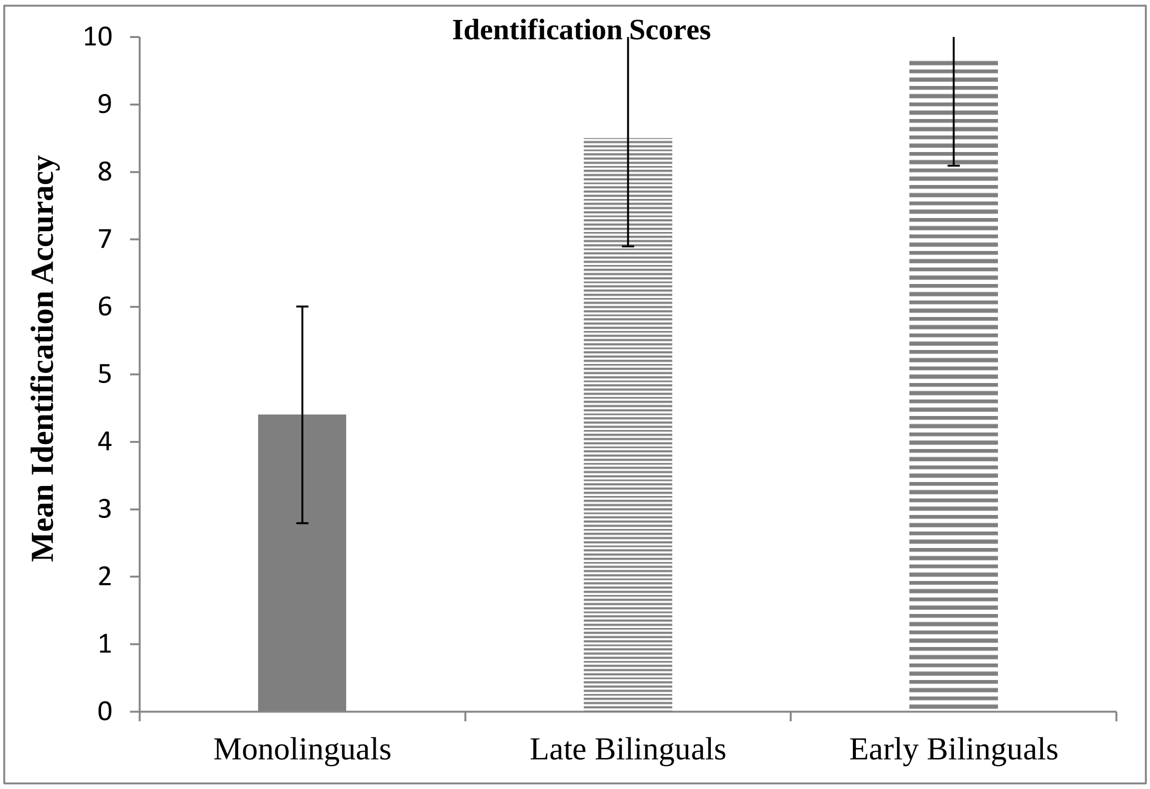

Figure 2. Participants' mean identification accuracy (maximum score =10), Error bars = Standard Error.

A significant overall main group effect was also evident for identification scores, χ^2 (2) = 44.34, p < .001. Bonferroni adjusted significance tests for pairwise comparisons revealed a significant difference for identification scores between monolinguals and both the bilingual groups (monolinguals (mean rank = 10.98) and late bilinguals (mean rank = 34.93), p < .001, monolinguals (mean rank = 10.98) and 'early' bilinguals (mean rank = 45.60), p < .001). However, there was no significant difference between late (mean rank = 34.93) and 'early' bilinguals (mean rank = 45.60) (p = .135).

Controlling background differences using Analysis of covariance (ANCOVA)

The results clearly showed a gradient of performance across groups, with both bilingual groups performing better than the monolingual group, and the ‘early’ bilinguals outperforming the late bilinguals (at least for naming). However, our background data revealed that there were significant differences in both SES and phonological memory (indexed by nonword repetition). Consequently, we also carried out an ANCOVA collapsing the word learning scores of two bilingual groups into a single group to eliminate the ceiling effect and comparing this group with the monolingual group while controlling for SES and nonword repetition. The effect of group on performance remained significant for both naming [$F(1, 56) = 31.35$, $p < .001$, $\eta^2=.359$] and identification tasks [$F(1, 56) = 42.02$, $p < .001$, $\eta^2=.429$], indicating that it was bilingualism rather than SES or phonological short-term memory that influenced novel word learning.

Exploring the effects of age of onset of bilingualism: Regression analysis

Our final analysis examined in more detail the effect of age of onset of bilingualism (indexed by speaking) on word learning, while controlling for SES and phonological memory (Pearson’s correlations were carried out prior to these regressions and are reported in Appendix 2). This regression confirmed that age of onset of bilingualism is a statistically significant predictor of word learning, even when SES and phonological memory are controlled for (see Table 2).

Table 2. Regression results examining predictors of word learning in bilinguals.

DepdVari	IndVari	B	SE	β	p value	R Square	OMS
Naming						.489	$p < .01$
	AOB(S)	-.571	.179	-.722	.003		
	SES	-.002	.147	-.003	.989		
	NWR	.212	.253	.104	.409		
Identification						.307	.004
	AOB(S)	-.445	.146	-.801	.004		
	SES	-.138	.120	-.307	.258		
	NWR	.217	.207	.152	.303		

Notes
DepdVari = Dependent variable, IndVari = Independent Variable, SE = Standard Error, R Square = R square (adjusted), OMS = Overall model significance, AOB(S) = age of onset of bilingualism indexed by speaking.

Discussion

In order to investigate whether the language learning mechanism is affected by bilingual experience, we examined the acquisition of novel words in monolinguals, late bilinguals and 'early' bilinguals. As predicted from previous research, we found a clear effect of bilingualism with 'early' bilinguals showing superior word learning compared to monolinguals (Kaushanskaya & Marian, 2009b; Kaushanskaya, 2012). However, critically, even the bilingual group with a later onset of bilingualism (the late bilingual group) also outperformed monolinguals and demonstrated a bilingual advantage in novel word learning, despite low proficiency and relatively late age of onset of bilingualism. This indicates that even when delayed, exposure to another language exerts a significant influence on language learning for bilingual speakers and facilitates word learning skills. The late bilingual advantage observed in the present study is in contrast with previous findings that only 'early' bilinguals benefitted from their bilingualism in novel word learning (Kaushanskaya & Marian, 2007). Indeed, even our ‘early’ bilinguals had acquired their second language relatively late, and later than the early bilinguals in other studies. Nevertheless, late bilinguals, despite showing an advantage over monolinguals, showed significantly poorer word learning than ‘early’ bilinguals, and overall age of onset of bilingualism was a significant predictor of word learning ability. This could be an effect of either proficiency or length of exposure, as these two were confounded in our sample (and indeed often will be). This replicates the earlier findings by Kaushanskaya and Marian (2007) who found an effect of length of exposure within late bilinguals on word learning measured through translation. That is, late bilinguals with longer second language exposure outperformed their counterparts with shorter exposure. Further research is required to determine whether length of exposure is a critical variable influencing the extent of a bilingual advantage in word learning.

Recently there have been proposals to consider bilingual word learning within the framework of bilingual inhibitory control (Kaushanskaya & Marian, 2009b; Kaushanskaya, 2012). The general idea is that tasks examining word learning skills involve selection of a target word and successful inhibition of all irrelevant words that are activated during target word learning (Kaushanskaya & Marian, 2009b). A robust bilingual advantage in inhibitory control has been often suggested for early bilinguals compared to late bilinguals (Tao et al., 2011). Therefore the performance difference between early and late bilinguals may be due to the differences in inhibitory control abilities. Inhibitory control is particularly required when the referents are familiar (the referent familiarity effect: Kaushanskaya, Yoo, & Van Hecke, 2013) as, for these stimuli, a word already exists in the participants’ other language(s) and this word will have to be inhibited.

However, the critical question is why did we observe an advantage in novel word learning for late bilinguals compared to monolinguals? Novel word learning involves encoding of unfamiliar phonological information (Kaushanskaya & Marian, 2009b) and mapping the phonological form onto its respective semantic referent. For the second language learner, there is a great emphasis on acquiring novel words. This leads to significantly increased experience in encoding unfamiliar phonological information.

This experience may result in greater proficiency in novel phonological encoding leading to an advantage for novel word learning in late bilinguals. It is possible that late bilinguals may only show an advantage in tasks that resemble learning conditions similar to second language acquisition (e.g., picture naming task in a classroom context). Once again, when, as in our experiment, familiar referents are used and therefore there is a need for inhibition of the name of the referent in the native language. This situation is commonplace for bilinguals (even later bilinguals), but for monolinguals is more rarely encountered. Hence, the advantage, even for late bilinguals, once again could be related to inhibitory control required for learning and retrieving new names for familiar referents.

A main difference from previous studies is that we tested learning using naming and identification rather than a translation task. This required all participants to retrieve novel words when presented with pictures rather than from a word in their first language. Although this confirms that an advantage in novel word learning is not a mere reflection of bilinguals' translation ability, it is likely that factors that are associated with task type would have influenced the learning. For instance, recent findings by Kan, Sadagopan, Janich and Andrade (2013) can be taken as an evidence for such task effects where the bilinguals showed a specific advantage for comprehension probes when word learning was assessed through a fast mapping task. Although in our study the 'early' bilinguals performed well, the learning task remained challenging for late bilinguals and particularly monolinguals, despite the fact that our study used only ten novel words for learning. This is considerably fewer than other studies (e.g. Kaushanskaya & Marian, 2009b; Kaushanskaya, 2012) and suggests that perhaps translation tasks are easier than naming. It is also possible that combination of the nature of the task and the relatively small number of items interacted to facilitate word learning specifically for our ‘early’ bilinguals.

Two other major factors should be considered in relation to our results: phonological short-term memory and SES. Phonological short-term memory has long been established as a strong predictor in the acquisition of novel words (e.g., Baddley, Gathercole, & Papagno, 2008). Papagno and Vallar (1995) have previously argued that a superior phonological short-term memory in multilinguals may enhance foreign vocabulary learning. There was indeed a significant difference across our groups in phonological short-term memory (measured using a non-word repetition task), and non-word repetition scores were predictors of naming and identification. Although this results indicates an effect of phonological memory on novel word learning bilingual status remained a predictor over and above these effects. This finding supports other reports (e.g., Kaushanskaya, 2012) that the differences in bilingual word learning needs to be accounted through measures beyond differences in phonological memory performance.

The three groups of participants in the present study also differed in their SES. The monolinguals came from a lower socio economic status than the late bilinguals who in turn were of lower SES than the ‘early’ bilinguals. This is quite different from an American context where early bilingualism is often linked with lower SES (Costa & Sebastián-Gallés, 2014). The role of higher SES in facilitating language and neurocognitive performance has been established in children (Noble, Norman, & Farah, 2005). It has also been found that SES and bilingualism may influence language (vocabulary) and executive functioning abilities independently (Calvo & Bialystok, 2014). While the relationship between adult word learning and SES remains unclear and worthy of future investigation, given that fact that SES is positively correlated with vocabulary acquisition, it may be reasonable to assume that higher

SES could be a potential contributor towards an enhanced word learning skills in ‘early’ bilingual performance. However, while SES was correlated with word learning score, once bilingual status and phonological working memory was taken into account in the regression, there was no longer a significant effect on word learning. This finding is in line with reports from cognitive processing literature suggesting that a bilingual advantage in cognitive control is not confounded by SES (de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012).

In conclusion, bilinguals in our study were more adept at learning novel words than monolinguals and this could not be accounted by differences in SES or phonological short term memory. These results indicate (i) unlike the cognitive advantage, even late bilingualism contributes a novel word learning advantage; and (ii) there is a direct association between extent of second language experience and word learning. We suggest that the late bilingual advantage in word learning may be restricted to only word learning tasks that bear significant similarities to vocabulary acquisition in second language bilingual word learning environments. Further research is required to test this hypothesis. Similarly, investigating the effect of other factors such as inhibitory control (Kaushanskaya, 2012) and SES in late bilingual word learning will offer further insights into the mechanisms underlying such advantages.

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Appendix 1

Novel words and English translations

Novel words	IPA	Translations in English
Hathi	haːt̪ʰɪ	Elephant
Chata	tʃʰaːt̪aː	Umbrella
Ainak	ænək	Spectacles
Kaechi	kæ̃tʃɪ	Scissors
Chammach	tʃammətʃ	Spoon
Batak	bat̪ak	Duck
Kitab	kit̪aːb	Book
Patang	pat̪aŋ	Flag
Chuha	tʃuːɦa	Rat
Kutha	kut̪t̪a	Dog

Appendix 2

Correlation analysis with age of onset of bilingualism as measured by speaking (AOB(S)) as a predictor for word learning in bilinguals.

Dependent Variable	AOB(S)	SES	NWR
Naming	-.692**	.578**	-.081
Identification	-.502**	.328*	.039
AOB(S)	—	-.850**	.258
SES	—	—	-.305

Notes
** p < .01, * p <.05, AOB(S) = Age of onset of bilingualism (speaking), SES = Socio- Economic Status, NWR= Non-Word Repetition

Chapter 5

Understanding bilingual word learning: The role of phonotactic probability and neighbourhood density

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Abstract

Previous research has shown that the language learning mechanism is affected by bilingualism resulting in a novel word learning advantage for bilingual speakers. However, less is known about the factors that might influence this advantage. This paper reports an investigation of two factors: phonotactic probability and neighbourhood density. Acquisition of fifteen novel concepts with novel names varying in phonotactic probability and neighbourhood density was examined in Mandarin-English bilinguals and English monolinguals. Bilingual speakers showed significantly better novel word learning regardless of the phonotactic probability and neighbourhood density patterns of the novel words. This indicates that the general facilitation of language learning mechanism subsequent to bilingualism is independent of linguistic influences from phonotactic and neighbourhood density effects.

Introduction

A large body of research has found converging evidence for a positive relationship between bilingualism and non-linguistic skills (e.g., Abutalebi, et al., 2011; Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006; Costa, Hernandez, & Sebastián-Gallés, 2008). In contrast to the bilingual advantage reported in the non- linguistic domain, studies examining the impact of bilingualism on linguistic skills have generally found a bilingual disadvantage. For example, it has been shown that bilinguals have more difficulty in recognising words in challenging (noisy) environments (e.g., Rogers, Lister, Febo Besing, & Abrams, 2006), have lower receptive vocabulary scores than monolinguals (e.g., Bialystok & Luk, 2012) and require longer time to retrieve words from mental lexicon (lexical access) (e.g., Bialystok, 2009; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Ivanova & Costa, 2008). Despite these reported disadvantages in linguistic processing, superior bilingual performance has been found for tasks associated with language (word) learning (e.g., Antoniou, Liang, Ettlinger, & Wong, 2014; Kaushanskaya & Marian, 2008, 2009b, 2012; Nair, Biedermann, & Nickels, 2015; Papagno & Vallar, 1995; Van Hell & Mahn, 1997).

Although evidence suggests a generally positive influence of bilingualism on word learning, the precise nature of these bilingual effects needs further investigation. More recent investigations with monolingual speakers have focused on how phonological and lexical properties of novel words may influence word learning outcomes. For instance, Storkel, Armbrüster and Hogan (2006) suggested that both phonotactic probability (frequency distribution of sounds and sound combinations) and phonological neighbourhood density (number of lexical items that share phonology with a target) affect word learning independently: monolingual adults demonstrate a disadvantage for learning words with high phonotactic probability but an advantage for words with high phonological neighbourhood density. Although phonotactic probability and phonological neighbourhood density are known to produce distinct word learning effects, it is unknown whether the superior ability to acquire novel words in bilinguals is influenced by these factors. For example, bilinguals have extensive experience in learning totally unfamiliar words in a second language. It is possible that this experience will generalise to better learning of novel words with lower phonotactic probability and lower phonological neighbourhood density words. Consequently, it is possible that a bilingual advantage may be more pronounced for learning words low in these properties compared to those higher in phonotactic probability and phonological neighbourhood density. To investigate these possibilities the present study examined the effects of bilingualism on novel word learning when phonotactic probability and phonological neighbourhood density were experimentally manipulated.

Studies investigating the effects of phonotactic probability and phonological neighbourhood density have generated differing results depending on the task demands (e.g., single word recognition, production, learning and non-word repetition). For example, in monolingual adults, high phonotactic probability is generally associated with facilitatory effects for word recognition (e.g., Garlock, Walley, & Metsala, 2001; Vitevitch & Luce, 1999) and non-word repetition (e.g., Vitevitch & Luce, 2005). In contrast, while a high neighbourhood density advantage has been suggested for word production (e.g., Vitevitch, 2002; Baus, Costa, & Carreiras, 2008) and word learning (e.g., Storkel et al., 2006) this is not the case for word recognition (e.g., Luce & Pisoni, 1998). Moreover, although a facilitatory effect of phonological neighbourhood density has been found for word production, significant body of research also reports inhibitory effects or a combination of facilitatory and inhibitory effects (see Sadat, Martin, Costa, & Alario, 2014 for a detailed discussion).

In the case of word learning there is evidence for phonotactic probability effects from developmental studies (e.g., Gray, Pittman, & Weinhold, 2014). For instance, Storkel (2001) found that pre-school children learned common sound sequences (high phonotactic probability) more accurately than rare sound sequences (low phonotactic probability). She also found that the larger the children's receptive vocabulary the larger the effects of phonotactic probability. In contrast to Storkel's (2001) results, Storkel and Lee (2011) found, the reverse: 4 year old children exhibited superior learning accuracy for rare sound sequences compared to common sound sequences. Hoover, Storkel and Hogan (2010) also reported similar advantages for rare sound sequences during word learning in children. Storkel and Lee (2011) argued that rare sound sequences would be more distinct from existing phonological representations. That is, upon hearing a novel word with common sound sequences, more known words will be activated, and the listener may try to match the input with the already activated words which may generate confusion and slow down the learning process. In contrast, rare sound sequences are less likely to activate more known words and therefore learning is triggered in the first exposure itself. In other words, words with low phonotactic probability will tend to have fewer phonological neighbours.

Inconsistent directions of effect are also not uncommon for phonological neighbourhood density. For example, Hollich, Jusczyk and Luce (2002) investigated lexical neighbourhood effects on 17 month old children using the headturn preference paradigm and found that infants only learned (looked longer at targets than nontargets) novel words from sparse neighbourhoods (low density) and did not show learning of novel words from dense neighbourhoods (high density). However, they also learned novel words from sparse neighbourhoods better than novel words with no neighbours. To account for these seemingly contradictory results, they suggested that while there is a competitive, inhibitory effect of density, there may also be an opposite, facilitation, effect for phonotactic probability. That is, having some familiarity with phonological patterns is helpful (enables faster processing of a new phonological pattern) but that too many similar items inhibits learning. In other words, the effects found for neighbourhood density, were influenced by phonotactic probability.

It is clear that developmental studies have found diverse effects of phonotactic probability and neighbourhood density on novel word learning. However, part of the problem may be due to the fact that most studies have only looked at one of the variables while not controlling for the potential effects of the other. However, Storkel, Armbrüster and Hogan (2006) examined the independent effects of these variables for adult novel word learning in the context of a story. When they examined partially correct responses (two out of three phonemes correct; as a measure of initial stages of word learning) a disadvantage for words with high phonotactic probability was evident compared to words with lower phonotactic probability. In contrast, the effect of phonological neighbourhood density was not significant. Initial learning performance did not vary between words of high and low density. These effects of phonotactic probability found during initial stages of word learning are different from developmental studies where a high phonotactic probability advantage is usually found (e.g., Storkel & Maekawa, 2005). For the later stages of word learning (i.e., when they analysed completely correct responses) Storkel et al. (2006) found no significant effect of phonotactic probability but there was an advantage for words of high neighbourhood density. It is most likely critical that this task involved a story context where novel words are not highlighted and must be detected. Storkel et al suggest that the advantage for low phonotactic probability words may be due to them being less word-like and hence more easily detected with detection triggering differing processing for novel words (learning) and known words (lexical access). In contrast, the advantage for words with high neighbourhood density during the later stages of word learning was suggested to be due to these words activating more neighbours from long term memory and these neighbours may facilitate acquisition (by for example, strengthening representations through feedback from shared phonemes).

The focus of most developmental and monolingual adult studies on word learning was to identify whether phonotactic probability and neighbourhood density produce inhibitory or facilitatory effects during novel word learning. However, if bilinguals demonstrate better novel word learning abilities than monolinguals, then it is important to understand whether the bilingual advantage in novel word learning is independent from the influences of phonotactic probability and neighbourhood effects of the novel words. In a broadly related study, Kaushanskaya, Yoo and van Hecke (2012) pointed out that increased second language experience particularly enhanced the acquisition of novel words that were phonologically unfamiliar paired with a familiar referent. Although it may be difficult to draw parallels between phonological familiarity and phonotactic probability, this preliminary finding seems to suggest that bilingual experience may specifically facilitate learning of less frequent sound combinations (words with low phonotactic probability). Therefore the critical question is whether the bilingual advantage for novel word learning is specific to only certain phonotactic patterns (e.g., words with low phonotactic probability) or whether bilinguals exhibit an overall word learning advantage regardless of the phonotactic patterns of the novel word. While there have been some attempts to investigate phonological familiarity effects on bilingual word learning (e.g., Kaushanskaya et al., 2012), to the best of our knowledge, this issue has not been investigated for phonological neighbourhood density.

The Inhibitory Control model for language production (Green, 1998) predicts that whenever an individual performs a novel task associated with language production, a specialised monitoring and control system known as the Supervisory Attentional System (SAS) is employed to ensure its successful completion. Although the role of SAS during learning is unclear however, it is likely that the SAS will be highly activated especially while encountering words that are unfamiliar in their phonological form (low phonotactic probability and low phonological neighbourhood density). However, as a result of prior bilingual experience of learning words with less frequent sound combinations and fewer neighbours in a second language, for bilingual speakers the SAS is already experienced in handling these novel tasks. This may therefore predict that a bilingual advantage emerges particularly for learning words with low phonotactic probability and phonological neighbourhood density.

Alternatively, it is also possible that the facilitatory effect of bilingualism for learning may extend to words with high phonotactic probability and high phonological neighbourhood density. This could be for two reasons. First, it could be that the benefits of bilingualism for word learning are a result of mechanisms that are not sensitive to phonotactic probability and phonological neighbourhood density: a general facilitatory effect of bilingualism. Alternatively, it could be that two separate mechanisms are facilitated by bilingualism – one, for items low in these factors (see above) and another for items high in these factors. Due to their high similarity to words, words with high phonotactic probability and phonological neighbourhood density may activate a comparatively greater number of words in the lexicon during learning. For learning to trigger, inhibition of these irrelevant words is required. Once again, the Supervisory Attentional System is suggested to play a role in inhibiting lexical competitors (Green, 1998; Abutalebi & Green, 2007). We argue that the inhibitory mechanism is required during learning tasks. Specifically, in order for learning to initiate, interference from non-target words will first need to be inhibited. It then follows that enhanced experience with using inhibition may result in bilinguals more efficiently inhibiting irrelevant words activated following the exposure of words with high phonotactic probability and neighbourhood density. If this is true then the bilingual advantage will extend to learning of high probability and density words. In effect we will see a bilingual advantage regardless of the phonotactic and phonological neighbourhood properties of the novel word.

Method

Participants

The participants were 20 monolingual native speakers of English and 20 Mandarin-English early, proficient, bilingual speakers. The bilingual participants were native speakers of Mandarin (L1) and had acquired English (L2) in a classroom context. All bilingual participants rated their second language proficiency across four language categories ranging from 0 (no proficiency) to 4 (native-like). Before the learning phase, subtests from Comprehensive Test of Phonological Processing (CTOPP, Wagner, Torgesen, & Rashotte, 1999) were used to test participants' non-word repetition and digit span abilities. Participant's demographic characteristics and self-ratings of bilingual language proficiency are reported in Table 1.

Table 1. Demographic and background data of participants. Means and standard deviations (in parentheses).

Demographic variables	**Monolinguals**	**Bilinguals**	**p value**
Age (years)	21.47 (.938)	21.55 (.998)	.807
Non-word repetition[a]	70.65 (6.70)	69.55 (7.39)	.625
Digit span[b]	68.1 (9.91)	69.55 (7.39)	.625
L2 acquisition age (speaking)		6.15 (.812)	___
Proficiency ratings[c]			
Speaking	___	3.05 (.394)	___
Listening	___	3.40 (.502)	___
Reading	___	3.35 (.489)	___
Writing	___	3.28 (.487)	___

Notes
N=20 for both participant groups
[a & b] Non-word repetition (n=18) and digit span (n=21) percentile scores (subtests of Comprehensive Test of Phonological Processing)
p value = significance of two-sample t-test (two tailed)
[c] Proficiency Ratings from 0 = not proficient to 4 = highly proficient

Materials

We created a set of bisyllabic non-words with varying phonotatctic probability and phonological neighbourhood density as calculated using the English vocabulary of the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). Before calculating both phonotactic probability and neighbourhood density we eliminated from CELEX any item for which the headword was a simple contraction, complex contraction, letter or abbreviation. We also eliminated any item with a spelling containing a non-alphabetic character (e.g. hyphen, space) or a capital letter in a position other than the first. This resulted in having a list of 65030 unique pronunciations. In cases where a pronunciation occurred in multiple entries the frequencies were summed to get a single total frequency for that specific pronunciation. This list was the basis for calculations of phonotactic probability and number of phonological neighbours.

For varying phonotactic probability and neighbourhood density, we adopted the procedure given by Storkel et al. (2006) & Hoover et al. (2010). Phonotactic probability was computed by calculating both positional segment frequency and biphone frequency for each word. Positional segment frequency is based on how frequent a single sound is in a given word position (e. g., the probability of the sound /k/ occurring in the first position such as in the word /kæt/) (Hoover et al., 2010). In order to calculate the positional segment frequency of each sound in a target (novel) word, initially, the sum of log frequencies of all words containing a particular sound (e.g., the sound /k/ in the above example) in a particular position (e.g., /k/ first position in the above example) was divided by the total sum of log frequency of all sounds in the same position (first position in the above example) (Hoover et al., 2010). Once the positional frequency of each sound was computed, these values were summed to calculate the summed positional segment frequency for each novel word.

Biphone frequency is defined based on how frequent a two sound combination is in a given word position (e. g., the probability of the sound /kæ/ occurring, as in the first position of the word /kæt/) (Hoover et al., 2010). Similar to positional segment frequency, biphone frequency was calculated based on the sum of log frequencies of all words containing a particular two sound combination (e.g., the sound /kæ/ in the above example) in a particular position (e.g., in the first position in the above example) and divided by the total sum of log frequency of all words containing any two sound combination in a given position (first position in the above example) (Hoover et al., 2010). Once the biphone frequency of each sound combination was computed, these values were summed to calculate the summed biphone frequency of a single novel word.

Phonological neighborhood density referred to the number of words that differed from the target word by a single phoneme addition, deletion or substitution based on the 65030 word vocabulary detailed above.

The original set of novel words (n=35) novel words were divided into sets of higher and lower phonotactic probability and phonological neighbourhood size based on a median split of each category (see Appendix 1 for detail of stimulus characteristics). From these lists we created two subsets: the first manipulated phonotactic probability and comprised novel words of higher and lower phonotactic probability but matched in neighbourhood density (both of lower neighbourhood density). The second subset manipulated neighbourhood density and comprised novel words of higher and lower neighbourhood density but matched in phonotactic probability (both higher in phonological neighbourhood density). Each of the 4 groups comprised 5 novel words as the lower phonological neighbourhood density and higher phonotactic probabilty subsets used the same stimuli, this resulted in a total of 15 novel words for learning[2].

[2] *We had originally hoped to be able to orthogonally contrast phonotactic probability and phonological neighbourhood density, but it proved not to be possible to create a set that were high in phonological neighbourhood density and low in phonotactic probability.*

In addition, the similarity of the target words to Mandarin was rated by 5 native speakers of Mandarin based on a 1-4 point rating scale (1 = no resemblance to Mandarin, 4 = close resemblance to Mandarin). The Mandarin similarity ratings for novel words and their other characteristics are given in Appendix 1.

Referents

Each novel word was paired with a novel picture as a referent. The pictures consisted of drawings of 144 novel alien creatures differing in physical appearance and characteristics (Gupta et al., 2004). For this study, we selected fifteen alien pictures from the Gupta et al. (2004) stimulus set in such a way that all fifteen were visually distinct. Each alien was also assigned with attributes (definition) relating to physical or mental characteristics of the alien (e.g. "/tæbɛk/ likes flowers and owns a beautiful garden") and unrelated to the physical appearance. The novel words and the definitions for each alien are given in Appendix 1.

Procedure

All 15 novel words were presented for learning in the same session(s). The word learning session followed background testing and completion of the language proficiency questionnaire. Each learning phase consisted of presentation of the referent picture on a Mac OS X 10.7 laptop monitor together with simultaneous presentation of an audio recording of the novel word. Pictures remained on the screen for 30 seconds, and were followed by the next stimulus. Following presentation of all stimuli, they were presented again in a different random order four more times. At the end of the final presentation the participants were asked to repeat the word aloud three times to maximize the learning.

Immediately following the five phases of word learning and one week later, each participant was assessed on the acquisition of the novel words using a picture naming and a definition to picture matching task. In the picture naming task, the target picture was presented and the participant was asked to name it as quickly as possible. The responses were audio recorded for later analysis.

In the definition to picture matching task, a definition was presented auditorily in a question form (e.g., "Can you show me the alien who likes flowers and owns a beautiful garden?") and the target had to be selected from three pictures. The pictures included the target referent, one semantically distractor and one phonologically related distractor from the stimulus set. None of the stimuli were presented more than 3 times during the task.

Analyses

Analyses were performed on response accuracy for each task. Only completely correct productions were accepted in the naming task.

For both naming and definition-picture matching tasks, we analysed separately the effects of phonotactic probability and neighbourhood density using the sets (described above) that were matched for the other variable. Accuracy for both naming and definition to picture matching was analysed using a 2 (language group: bilingual/monolingual) × 2 (phonotactic probability or neighbourhood density: higher/lower) × 2 (testing time) repeated measures of analysis of variance (ANOVA) with language groups as between subject effects and phonotactic probability or neighbourhood density and testing time as within subject effects.

Results

Naming

Figure 1 provides the results of the naming task for sets manipulating phonotactic probability and phonological neighbourhood density in both language groups (bilinguals and monolinguals across testing time (immediate and delayed).

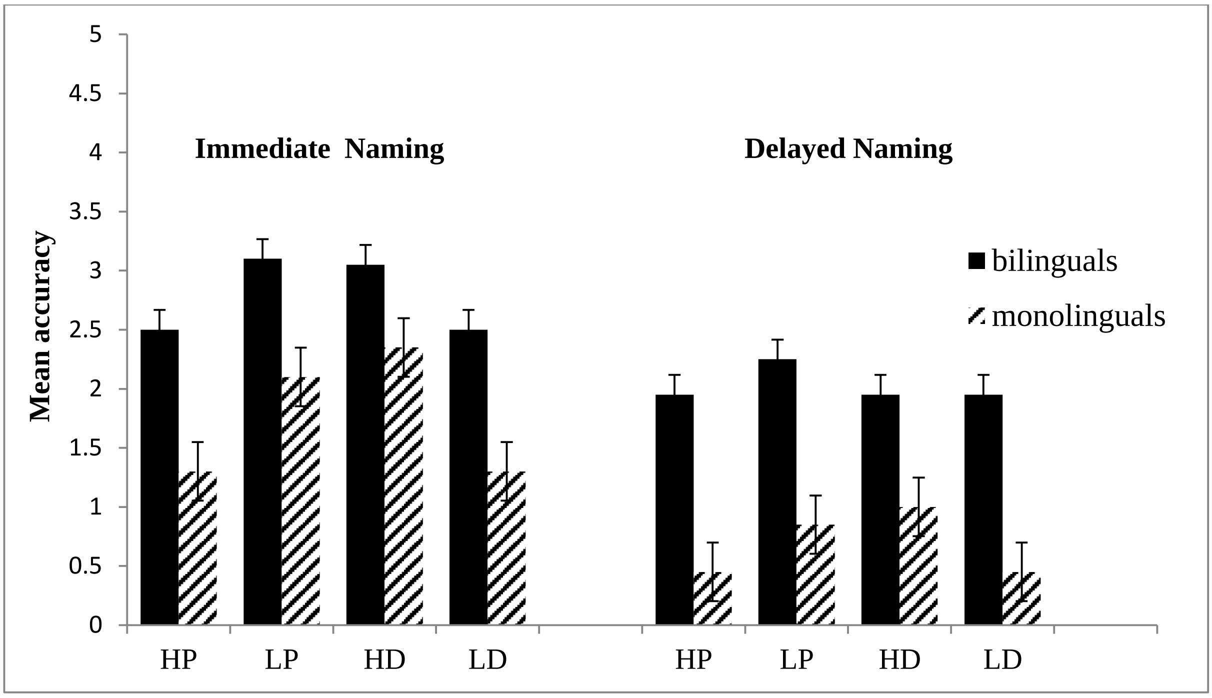

*Figure 1.*Mean name accuracy scores for bilinguals and monolinguals during immediate and delayed testing (HP = words with high phonotactic probability, LP = words with low phonotactic probability, HD = words with high phonological neighbourhood density, LD = words with low phonological neighbourhood density)

Phonotactic probability analysis

There was a highly significant main effect of group indicating better naming for bilinguals compared to monolinguals [F (1, 19) = 25.61, p < .001, η^2_p =.574]. The main effect of time was also significant [F (1, 19) = 41.19, p < .001, η^2_p =.684] with better naming immediately compared to delayed testing. There was also a significant main effect of phonotactic probability [F (1, 19) = 41.95, p = 001, η^2_p =.445], indicating that lower probability words were better learned than higher probability words (lower probability: bilinguals: M = 3.10, SD = 1.16, SE = .280, 95% CI:[2.53, 3.66]); monolinguals: (M = 2.10, SD =1.33, SE=.280, 95% C1:[1.53, 2.66]); higher probability words (bilinguals: M = 2.50, SD=1.31, SE = .310, 95% CI:[1.87, 3.12]); monolinguals: (M = 1.30, SD = 1.45, SE = .310, 95% CI:[.672, 1.92]). None of the interactions were significant (group and phonotactic probability [F (1, 19) = .474, p = .50, η^2_p =.024]; group and time [F (1, 19) = 1.22, p = .283,

η^2_p =.060]; time and phonotactic probability [F (1, 19) = .1.85, p = .189, η^2_p =.089]; group, time and phonotactic probability [F (1, 19) = .042, p = .839, η^2_p =.002]). This showed (amongst other things) that the bilingual advantage did not vary according to phonotactic probability.

Phonological neighbourhood density analysis

The main effect of group was significant indicating bilinguals showed more accurate naming than monolinguals [F (1, 19) = 16.54, p = .001, η^2_p =.465]. The main effect of time was significant [F (1, 19) = 9.94, p = .005, η^2_p =.334] with more accurate naming immediately compared to delayed.

The main effect of phonological neighbourhood density was significant [F (1, 19) = 63.60, p < .001, η^2_p =.770] with higher accuracy for high density words (bilinguals: M = 3.05, SD = 1.46, SE = .328, 95% CI:[2.36, 3.73.]); monolinguals: (M = 2.35, SD = 1.18, SE=.264, 95% C1:[1.79, 2.90]) than low density words (bilinguals: M = 2.50, SD = 1.31, SE = .295, 95% CI:[1.88, 3.11]); monolinguals: (M = 1.30, SD = 1.45, SE = .325, 95% CI:[.619, 1.98]).

None of interactions were significant (group and phonological neighbourhood density [F (1, 19) = .672, p = .422, η^2_p =.127]; group and time [F (1, 19) = 2.77, p = .112, η^2_p =.127;, time and phonological neighbourhood density [F (1, 19) = 2.70, p = .117, η^2_p =.125]; group, time and phonological neighbourhood density [F (1, 19) = .009, p = .925, η^2_p =.000]). Once again this indicated (amongst other things) that the bilingual advantage did not differ across high and low phonological neighbourhood density novel word learning.

Definition-picture matching task

Figure 2 presents definition-picture matching accuracy data for both phonotactic probability and phonological neighbourhood density in both language groups (bilinguals and monolinguals across testing time (immediate and delayed).

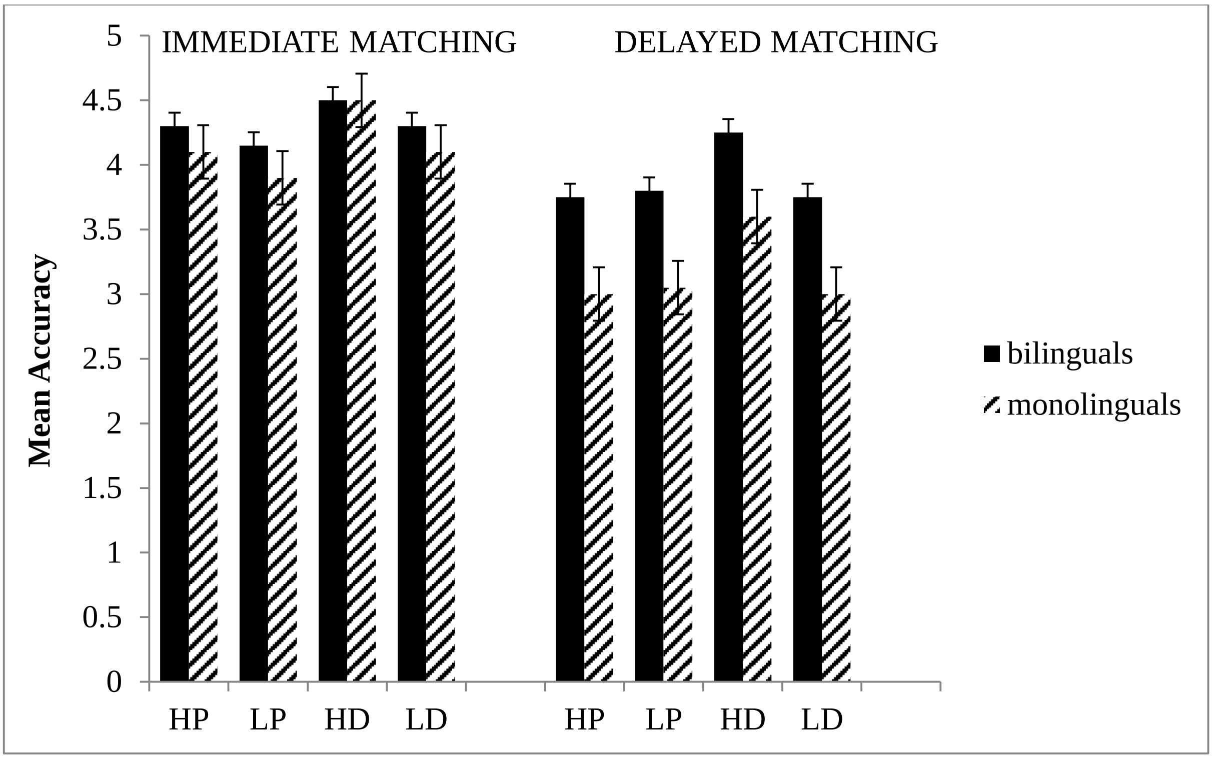

Figure 2. Mean definition-picture matching accuracy scores for bilinguals and monolinguals during immediate and delayed testing (HP = words with high phonotactic probability, LP = words with low phonotactic probability, HD = words with high phonological neighbourhood density, LD = words with low phonological neighbourhood density)

Phonotactic probability analysis

There was an overall main effect of group [F (1, 19) = 6.16, p = .023, η^2_p =.245]: Once again bilinguals performed better than monolinguals. The main effect of phonotactic probability was significant [F (1, 19) = 26.71, p < .001, η^2_p =.584]. In contrast to naming, there was greater accuracy for high probability words than low probability words.

The main effect of time was not significant [$F(1, 19) = .289$, $p = .597$, $\eta^2_p = .015$] indicating that accuracy of definition-picture matching did not differ significantly between immediate and delayed testing. Nor were there any significant interactions (group and phonotactic probability [$F(1, 19) = 1.63$, $p = .216$, $\eta^2_p = .079$]; group and time [$F(1, 19) = .000$, $p = 1.00$, $\eta^2_p = .000$]; time and phonotactic probability [$F(1, 19) = 1.00$, $p = .330$, $\eta^2_p = .050$]; group, time and phonotactic probability [$F(1, 19) = .000$, $p = 1.00$, $\eta^2_p = .000$]). Hence, as in naming, bilinguals had better overall accuracy for definition to picture matching regardless of phonotactic probability.

Phonological neighbourhood density analysis

There was a significant main effect of group [$F(1, 19) = 7.66$, $p = .012$, $\eta^2_p = .288$] – bilinguals once again outperformed monolinguals. The main effect of time was also significant [$F(1, 19) = 10.49$, $p = .004$, $\eta^2_p = .356$] with greater accuracy at immediate testing. Finally, there was a significant effect of phonological neighbourhood density [$F(1, 19) = 23.14$, $p < .001$, $\eta^2_p = .549$] with better accuracy for high density words than low density words.

None of interactions were significant (group and neighbourhood density [$F(1, 19) = 1.94$, $p = .179$, $\eta^2_p = .093$]; group and time [$F(1, 19) = .393$, $p = .538$, $\eta^2_p = .020$]; time and neighbourhood density [$F(1, 19) = 1.95$, $p = .179$, $\eta^2_p = .093$]; group, time and neighbourhood density [$F(1, 19) = .067$, $p = .799$, $\eta^2_p = .003$]).

Discussion

This study examined whether bilingual advantages that have been found for novel word learning (Kaushanskaya & Marian, 2009b) are influenced by the phonotactic probability and phonological neighbourhood density of the novel words. In order to investigate this, we compared the performance of bilinguals and monolinguals in a word learning task that manipulated the phonotactic probability and phonological neighbourhood density of the novel words. We found that bilinguals outperformed monolinguals in word learning as measured by both picture naming and definition to picture matching. Moreover, there was no influence of either phonotactic probability or phonological neighbourhood density on the extent of this bilingual advantage. However, before we turn to discuss result in detail we will first examine the effects of phonotactic probability and phonological neighbourhood size on learning.

For the phonological neighbourhood density manipulation, the results were consistent across tasks: the higher the neighbourhood density, the better the learning. Our results therefore replicate Storkel et al.'s (2006) findings on adult word learning in a story context, although contrast with, for example, Hollich et al.'s (2002) finding for infant learning. Storkel et al suggested that the advantage for high neighbourhood density words could be due to better consolidation of representations through the links with many neighbours. They suggest, for example, that the activated neighbours of the novel word will activate their phonemes, and these phonemes may then feedback their activation to the novel word. This interactive process results in strengthening of the representation for the novel word.

For phonotactic probability, however, the results differed across tasks (naming and definition-picture matching): Both bilinguals and monolinguals demonstrated better accuracy for naming of lower phonotactic probability words, while for definition-picture matching the reverse was true, with higher probability words being more accurate. It is unclear what drives these effects. The effect found for naming is consistent with that found by Storkel et al. (2006), however, they only found an effect of phonotactic probability for the initial stages of learning, arguing that learning was triggered better when the stimuli were more novel. However, this explanation seems less appropriate to a context where the words are explicitly flagged as novel (and do not need to be detected in a story context). Moreover, in that the explanation relates to learning might be expected to affect both our tasks in a similar way. The most likely possibility to account for the different patterns is that they were perhaps driven by task effects. For instance, in the definition-picture matching task, participants saw the picture of the target alien (along with distractors with phonologically similar names) and were asked to match the definition to the correct alien, It is possible that the necessity to retrieve names of multiple aliens and match them to the name evoked by the target in some way favoured high probability items. However, the precise mechanism by which this may have occurred remains unclear.

Let us now turn to the fact that bilinguals performed better on this learning task than monolinguals. In the Introduction, we suggested two possible pattern of advantage. Either bilinguals may have only shown an advantage specifically for words with low phonotactic probability and low phonological neighbourhood density. We hypothesised that this advantage could be due to the increased novelty associated with learning these comparatively unfamiliar words, resulting in a greater requirement for use of the Supervisory Attentional System (Green, 1998).

The alternative pattern was that bilinguals could show an advantage for all stimuli. This was the pattern supported by our data: bilinguals performed more accurately in novel word learning irrespective of the phonotactic probability and phonological neighbourhood density of the stimuli, and across both naming and identification tasks. This finding replicates the previous research demonstrating facilitatory effects of bilingualism for novel word learning (e.g., Kaushanskaya & Marian, 2009a 2009b; Nair, Biedermann, & Nickels, 2015). We suggested that such a pattern could be accounted for in, at least, two ways: The general advantage could be due to a bilingual benefit for word learning that is not affected by either phonotactic probability or phonological neighbourhood density. Alternatively, it may be that bilinguals are advantaged for both low and high phonotactic probability/neighbourhood density due to the efficient working of the specialised Supervisory Attentional System (Green, 1998).

Let us consider the second account first. It is likely that the Supervisory Attentional System (SAS) plays an important role in the learning process. In the Introduction we suggested that the SAS may have different roles in the learning of low and high probability/density words. We will not reiterate these arguments here; suffice to say that it is unclear whether there are separate mechanisms at play facilitating the acquisition of each set of items. It is also possible however, that the SAS is responsible for the bilingual advantage as a result of the same basic mechanism for both types of stimuli. For instance, this mechanism is specialised in handling novel tasks. In such a context, it is likely that the system would consider learning any novel words as a novel task regardless of their phonotactic probability/neighbourhood density properties. Once the system identifies the novelty associated with the task, it leads to the activation of attentional resources that are needed to initiate learning. We suggest that learning of the both low and high phonotactic probability/neighbourhood density could be mediated through these attentional resources released by the Supervisory Attentional System.

In considering the first possibility, although there may specific mechanisms at play for word learning such as the one described above, one must not overlook the fact that early experience with a second language could facilitate the overall language learning mechanism in general. For instance, in this case, an advantage for low phonotactic probability items could be the result of bilinguals’ prolonged experience with encoding and storing unfamiliar phonological forms and referents in a second language (Kaushanskaya & Marian, 2009b). However, this benefit may not be necessarily be confined to low phonotactic probability words and could generalise to all novel words including words with high phonotactic probability and neighbourhood density.

Another way to look at these results is in relation to the bilingual’s phonological system. For instance, Kaushanskaya and Marian (2009b) have argued that experience with more than one language makes the bilingual’s phonological system comparatively more open. It then suggests that the bilingual's phonological system is more open in accepting any phonological combinations - including those of low phonotactic probability. This is in contrast to the specific phonological tuning that occurs for monolinguals in their native language. This open phonological system may therefore further help boost the phonological encoding abilities that are critical to word learning.

There are, of course, limitations related to the current study. First, while the rated similarity to Mandarin for our stimuli was very low, we did not explicitly manipulate or control for phonotactic probability and neighbourhood density in Mandarin as well as English. We therefore cannot be sure how far the manipulation of these variables may have been slightly different for the bilinguals. It is possible for example that all stimuli may have been of slightly higher phonotactic probability and neighbourhood density for the bilinguals. We cannot exclude this as a possibility, and future research should examine this potential confound from L1. Second, it would have been preferable to orthogonally manipulate neighbourhood density and phonotactic probability, however, at least within our stimuli this was not possible.

Conclusions

The present study replicates previous findings of a bilingual advantage in novel word learning and provides two important contributions to the literature: a) It demonstrates that the facilitatory effects of bilingualism on novel word learning are relatively stable even when the phonotactic probability and neighbourhood density of the novel words are varied; and b) the loci of these advantages may be an efficient Supervisory Attentional System. Our results also reinforce the fact that word learning can be powerful tool to further shed more insight into the relationship between language learning and cognitive control.

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Appendix 1

Novel word categories and their characteristics (all mean values)

Novel Word Categories	High Density High Probability	Low Density Low Probability	Low Density High Probability
Phonological Neighbourhood Density	5.20	0	.20
Positional Segment Frequency	0.37	0.18	0.38
Biphone Frequency	0.03	0.01	0.03
Mandarin Similarity Rating	1	1.20	1

Note
Mandarin Similarity Rating for novel word (1 = no resemblance to Mandarin, 4 = close resemblance to Mandarin).

Appendix 2

Novel word categories | Definitions

High Density-High Probability

fɒni:s can sing beautifully and is known as the heavenly singer.

pɪkɪn lives on mars and owns a big crystal house.

rɛdɪn can turn stones into diamonds.

mi:lit creates water and rain in the sky.

dɪtaɪz can create thunder and lightning from his eyes.

Low Density- Low Probability

mɪgæk owns a powerful elephant which has seven heads.

lɛvrəʊ enjoys the beauty of the shining stars.

mi:ɒp is interested in paintings and fine arts.

trɒgɛm travels to earth in a carriage pulled by five horses.

tæbɛk likes flowers and owns a beautiful garden.

Low Density- High Probability

tɪsɪv is the eldest alien and the head of the alien family.

dɪmtɛz enjoys chocolate, milk and sweets very much.

tʃɒnɪd is very knowledgeable and is regarded as an experienced teacher.

sɛna:k is very good at healing diseases.

sɪsrɛt is fond of travelling and driving around space .

Appendix 3

Stimuli characteristics, median, mean and standard deviation

Novel words	PN	PSF	BF
fɒni:s (HD-HP)	4	.34	.02
pɪkɪn (HD-HP)	7	.45	.02
rɛdɪn (HD-HP)	4	.36	.03
mi:lit (HD-HP)	4	.36	.03
dɪtaɪz (HD-HP)	7	.32	.04
mɪgæk (LD-LP)	0	.22	.01
lɛvrəʊ (LD-LP)	0	.17	.00
mi:ɒp (LD-LP)	0	.13	.00
trɒgɛm (LD-LP)	0	.20	.02
tæbɛk (LD-LP)	0	.18	.01
tɪsɪv (LD-HP)	1	.40	.03
dɪmtɛz (LD-HP)	0	.40	.04
tʃɒnɪd (LD-HP)	0	.33	.02
sɛna:k (LD-HP)	0	.31	.02
sɪsrɛt (LD-HP)	0	.46	.03

Notes
HD-HP = High phonological neighbourhood density-High phonotactic probability
LD-LP =Less phonological neighbourhood density-Low phonotactic probability
LD-HP = Less phonological neighbourhood density-High phonotactic probability
PN = Phonological Neighbourhood Density
Phonological Neighbourhood Density (minimum = 0, maximum = 28, median = 1, M= 2.86, SD = 3.81)
PSF=Positional Segment Frequency
Summed Positional Segment Freq (minimum = 0.002, maximum = 0.805, median = 0.303, M = 0.302, SD = 0.104)
BF=Biphone Frequency.
Summed Biphone Freq (minimum = 0, maximum = 0.137, median = 0.023, M = 0.025, SD = 0.017)

Chapter 6

Summary and Conclusions

General Discussion and Conclusions

The main goal of this thesis was to extend previous research examining the consequences of bilingualism in both cognitive and linguistic domains, particularly focusing on:

1. The effect of socio-economic status on bilingual cognitive control (**Chapter 2**);

2. The effect of bilingualism on sentence recognition (**Chapter 3**);

3. The effect of late bilingualism on novel word learning abilities (**Chapter 4**);

4. The effect of phonotactic probability and neighbourhood density on novel word learning in bilingual speakers (**Chapter 5**).

This chapter will both summarise the main results of these four studies and discuss them in relation to key themes that are important when studying bilingual performance. This includes discussion in the context of the theoretical models presented in Chapter 1, and the broader (clinical) implications of these results.

Bilingualism, Socio Economic Status and Cognitive control: Chapter 2

Summary of experimental results: Chapter 2

Chapter 2 contained two experiments: In Experiment 1, we examined whether Malayalam-Tulu bilingual illiterates of lower socio-economic status performed better than Malayalam monolingual illiterates on cognitive processing tasks such as conflict resolution and monitoring. Cognitive processing abilities were assessed in two different experiments, both of which used tasks which are hypothesised to require conflict monitoring and resolution: Experiment 1 used the Simon task (Simon & Berbaum, 1990; Simon & Small,

1969) and Experiment 2 used the Attentional Network Task which includes the Flanker task (Fan, McCandliss, Sommer, Raz, & Posner, 2002).

In both experiments bilinguals responded faster overall than monolinguals for both congruent and incongruent trials, replicating the past findings of a global advantage in bilinguals (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004). Given the lower socio-economic status of our participants, this therefore demonstrates that the bilingual advantage is not due to a confound with socio-economic status and is even present when participants are illiterate.

Our findings were less consistent when examining whether bilinguals showed a smaller congruency effect than monolinguals. In the Simon task there was no significant interaction between language group and congruency (i.e., no Congruency/Simon effect). Although in the Attentional Network Task, bilinguals exhibited a reduced congruency effect compared to monolinguals once again this was statistically non-significant.

The Attentional Network Task also examined different attentional mechanisms such as executive, alerting and orienting networks. The results demonstrated no specific bilingual advantage for the executive network (difference in reaction time between incongruent and congruent trials), alerting network (difference in reaction time between trials preceded by no cue and spatial cue) and orienting network (difference in reaction time between trials preceded by the centre cue and spatial cue). These results are inconsistent with findings from Costa, Hernandez and Sebastián-Gallés (2008) who found a specific bilingual advantage for executive and alerting networks.

Discussion and Implications

The results of Chapter 2 must be discussed in relation to two separate issues: (i) Effects of bilingualism and (ii) effects of socio- economic status.

Regarding the effect of bilingualism, the results clearly showed a global advantage, generally referred to as the ‘‘Bilingual Executive Processing Advantage’’ (BEPA). An advantage in bilinguals for congruent and incongruent (trials with and without conflict) has been linked to enhanced conflict monitoring skills. For example, Costa, Hernández, Costa-Faidella and Sebastián-Gallés (2009) have argued that when trials with and without conflict are mixed (e.g., congruent, incongruent and neutral), in order to identify the conflict, participants also need to monitor the conflict (that is plan ahead for trials on which the conflict is present). This would then lead to a heightened activation of conflict monitoring mechanisms leading to a bilingual advantage in all trials. Although this issue is not as straightforward as it seems to be, neuroimaging studies seem to provide further evidence for the role of conflict monitoring in cases of an observed bilingual advantage. Neuroimaging evidence suggests the role of anterior cingulate cortex, a region in the medial frontal lobe that has been found to be significant for executive functioning specifically for conflict monitoring. This region has been shown to have enhanced activation associated with bilingualism indicating that a bilingual experience may tune this region especially for executive processing tasks (Abutalebi et al., 2011).

In Green’s (1998) Inhibitory Control model, while inhibition is a key task for the supervisory system, the role of this mechanism is not confined to inhibitory abilities. Recently, it has been also proposed that, the level of cognitive control varies in bilinguals depending on the language context (e.g., dual language with the frequent use of two languages; Adaptive control hypothesis, Green & Abutalebi, 2013). That is, bilinguals recruit control abilities such as conflict resolution and conflict monitoring in contexts where individuals need to constantly use two languages for communication For example, in the context of our participants, Malayalam is spoken at home and Tulu is used for social needs such as communicating with neighbours. Given that bilingual control mechanisms are not limited to inhibitory control abilities, we argue that the supervisory attention system must be able to manage most of the cognitive control requirements needed for language processing. Therefore, the global advantage found in bilinguals can also be accounted by Green's Inhibitory Model.

Second, the most critical aspect of this study was that bilinguals of lower socio-economic status showed a processing advantage compared to monolinguals who shared the same social background. The effect is amplified by the fact, that all participants (regardless of language skills) were illiterate. This is the most powerful context in which we could demonstrate a bilingual advantage. The result is critical, given that much controversy has been generated regarding the lack of adequate control of socio-economic status (see Hilchey & Klein, 2011 for a review; also see Morton & Harper, 2007; and Bialystok, 2009 for a reply to Morton & Harper, 2007). Some studies have shown that the bilingual advantage diminished when the socio- economic status was controlled (Morton & Harper, 2007). This seemed to suggest that only bilinguals from higher socio-economic status should demonstrate a bilingual advantage. Importantly, this was not the case for our results. We also argue that it is bilingual language context rather than socio-economic status that might be important. For example, the experience of bilingualism associated with class room learning may be different in its effects from the bilingualism experience of migrants, and these may both in turn have different effects from the bilingual experience for people for whom bilingualism is a lifelong part of everyday experience.

The task of linking language context with cognitive control processes has been elegantly outlined in Green & Abutalebi's (2013) Adaptive Control hypothesis. Of all the language contexts mentioned in this hypothesis, the dual language context is described as that where the bilingual speaker must use a number of cognitive control processes including cognitive resolution (supressing words in a non-target language) and monitoring (monitoring interference from a non-target language). Our bilinguals lived in a language context where switching between languages was a key part of everyday bilingualism: These bilinguals spoke Malayalam at home and Tulu in the wider community. Although we did not measure the average number of language switches for each bilingual per day, a conservative estimate would put this at around 30-40 times/day. As outlined in the Adaptive Control hypothesis, this multiple switching is likely to have multiple consequences for cognitive control mechanisms

Bilingualism and Sentence Recognition: Chapter 3

Summary of experimental results: Chapter 3

The main aim of this study was to examine whether bilingualism is negatively associated with the ability to recognizing sentences in the presence of a non-linguistic distractor such as environmental noise. We tested Malayalam-Tulu bilingual and Malayalam monolingual individual's ability to recognise and repeat sentences in their native language (L1) when the sentences were presented in acoustically degraded (with noise) and non-degraded (quiet) conditions. We found no evidence for different performance between bilinguals and monolinguals even in the presence of noise. This contrasts with previous studies that showed a bilingual disadvantage for recognising words when the stimuli were acoustically degraded with noise (e.g., Mayo, Florentine, & Buus, 1997; Rogers, Lister, Febo, Besing, & Abrams, 2006). We suggest that the use of sentence (rather than word) repetition, and testing in participants' native language (rather than L2) may have contributed to the differing results.

Implications and Discussion

Chapter 3 found no costs or benefits associated with bilingualism for sentence recognition. Given that bilinguals jointly co-activate both languages even in auditory word comprehension (e.g., Shook & Marian, 2013), bilinguals should have interference from two sources. First, when hearing a sentence, both the target and the non-target language are activated, and this interference needs to be controlled. Second, in this task the auditory input itself is acoustically degraded with the addition of noise, hampering phonological cues. Both of these sources of interference would lead to greater dilemma for bilinguals when selecting the best lexical candidates (compared to monolinguals who only have one source of interference). As our experiment contained semantically unpredictable sentences this would have further reduced the ability for the subjects to use contextual familiarity to support lexical selection. In this context, bilinguals would be required to use extra attentional resources to overcome the interference from multiple sources: Interference from another language at the level of lexical selection and interference from noise combined with reduced contextual familiarity of the sentences.

In the Bilingual Interactive A model (Dijkstra & Van Heuven, 2002) the attentional mechanism for overseeing task performance (for visual word recognition) is recruited from the task schema. We suggest that such a task schema (extended to another modality) could assist in overcoming interference in auditory word comprehension tasks, especially when faced with multiple sources of interference. We suggest that one possibility for the similar performance of bilinguals to monolinguals is that their extensive experience of managing interference (from managing their language use) has created a highly efficient task schema. However, more evidence is required to obtain clarity on this issue.

Bilingualism and Language Learning Mechanisms: Chapters 4 and 5

Summary of Experimental Results: Chapter 4

This chapter examined the facilitatory effects of bilingualism associated with language learning tasks. More specifically, we were interested in the effect of later onset bilingualism on novel word learning, comparing Tamil monolingual speakers and late and early onset Tamil-English bilinguals. We designed a novel word learning task using real words from a previously unknown (non-cognate) language (Hindi). While early bilinguals showed the best word learning performance, critically, our results also showed that the late bilinguals performed better than monolinguals. While an overall bilingual advantage in novel word learning is in line with previous findings (e.g., Kaushanskaya & Marian, 2009b), a specific bilingual advantage for late bilinguals contrasts with past studies (e.g., Kaushankaya & Marian, 2008).

Summary of Experimental Results: Chapter 5

In the final experimental chapter we studied the mechanisms responsible for novel word learning patterns found in bilinguals. Specifically, we examined if phonotactic probability and neighbourhood density influenced the bilingual advantage in novel word learning. Our results demonstrated better word learning accuracy for Mandarin-English late bilinguals compared to English monolinguals confirming the facilitatory effects of bilingualism for novel word learning (e.g., Kaushanskaya & Marian, 2009b; Nair, Biedermann, & Nickels, 2015) regardless of the degree of phonotactic probability or the phonological neighbourhood density of stimuli. These results illustrate that bilingual effects on novel word learning are not constrained by phonotactic probability or neighbourhood density but we suggest may emerge from the superior functioning of supervisory attentional mechanisms in bilinguals.

Turning to the effects of the two variables: For phonological neighbourhood density, novel words with more neighbours were learned better by both language groups and when learning was measured both using picture naming and using definition-to-picture matching. However, the phonotactic probability manipulation showed a different pattern: When learning was measured using naming, both language groups exhibited an advantage for learning words with low phonotactic probability. However, this effect was reversed for the definition-to-picture matching task: Both language groups demonstrated better accuracy for novel words with high phonotactic probability.

Implications and Discussion

The results of Chapters 4 and 5 confirm that language learning has been positively affected by bilingualism. With the exception of a few studies (e.g., Bartolotti & Marian, 2012; Bartolotti, Marian, Schroeder, & Shook, 2011; Kaushanskaya & Marian, 2009b) the effect of bilingualism in this domain is under-researched. The results from Chapter 4 demonstrated that a bilingual advantage is possible even when the onset of bilingualism is delayed. Although the late bilinguals in the study had lower second language proficiency than the early bilinguals, they still showed superior learning to monolinguals. We cannot however, determine whether language proficiency or age of acquisition modulates the bilingual advantage. It remains to be seen whether increases in the second language proficiency in late bilinguals also increases their novel word learning skills to levels comparable with early bilinguals.

Chapter 5 aimed to further understand the mechanisms responsible for bilingual advantage in novel word learning. Bilinguals and monolinguals showed the same pattern across learning regardless of phonotactic probability and neighbourhood density - with, once again, bilinguals showing better learning overall. We suggested that this pattern could be due to modulation of learning by the Supervisory Attentional System in the Inhibitory Control model (Green, 1998), recruiting additional attentional resources that are needed for word learning regardless of phonotactic probability and phonological neighbourhood density.

Extending these results to language learning more generally, it is likely that the control mechanisms used for novel word learning may vary depending on the language context. If for example, novel words in the second language are learned through an immersion background, then it is likely that learning may be modulated through control mechanisms used for single language contexts such as non-target lexical suppression (Adaptive Control hypothesis, Green & Abutalebi, 2013). For instance, in this single language context individuals may make use of more interference control to supress the dominant language in order to enhance learning in the non-dominant (non-native) language. In contrast, if the novel words are learned through a natural dual language environment, then additional control mechanisms such as interference control may be activated twice as often because of the frequent use of two languages. Therefore it is likely that participants in dual language context may show superior learning, however this assumption requires further testing. We suggest that novel word learning is a potentially powerful methodology to test the adaptive control hypothesis in relation to the influence of language context.

Theoretical implications: Cognitive control, language processing and learning

Our overall results suggest that bilingualism produces an overall positive effect in the domain of cognitive control and word learning. Although we found no effect of bilingualism on sentence recognition, the results also showed that there was no cost associated with bilingualism in this domain. One conclusion that arises from these results is that the bilingual advantages obtained in the domain of cognitive control and word learning may stem from the same source. That is, as discussed earlier, the general word learning advantage in bilinguals stems from enhanced cognitive control ability. Recall that our results from two word learning experiments suggested that both bilinguals and monolinguals exhibited similar short term memory ability, a skill critical for supporting novel word learning. Although short term memory did not differ between language groups, bilinguals exhibited superior word learning performance in both experiments. We argue that these advantages emerge from a general enhancement of cognitive control. We suggest that the supervisory attentional mechanism in the inhibitory control model may explain most of these advantages. While this can account for why bilinguals showed an advantage for novel word learning, the absence of a bilingual advantage for word recognition in our results is interesting given that previous researchers have claimed that there is a bilingual disadvantage in this domain (e.g., Bradlow & Alexander, 2007). It is possible that the non-significant effect is the result of an efficient task schema (a mechanism similar to supervisory attentional mechanism in the BIA+ model) that is activated preventing incorrect identification and recognition of words, and improving the number of words recognised correctly. Once again, what the specific cognitive control mechanism is that is recruited for word recognition is hard to predict (e.g., inhibition or selection) because it is possible that the task schema in BIA+ models may comprise a combination of inhibitory skills and selective attention skills. Both of these skills are needed for word recognition to attend to and select the target word and inhibit non-target words within and across languages.

Although it is reasonable to argue that both word learning and recognition tasks are supported by cognitive control mechanisms, it is important to note that the effects on bilingualism are subject to the nature of the tasks. Recall that research has previously found a negative effect of bilingualism associated with picture naming (e.g., Gollan, Montoya, Fennema-Notestine, & Morris, 2005). Interestingly, when naming was associated with word learning, this effect was reversed. That is, we found a bilingual advantage for word learning when measured by picture naming. These task effects have important theoretical implications as they suggest that the positive effects of bilingualism may be task constrained even when there is some amount of similarity in the task used (e.g., picture naming task for word production and learning). It is clear from our results that although inconsistencies across tasks exist, overall, bilingual effects can be explained through the inhibitory control and BIA+ models. In sum, the four experimental results of this thesis are not mutually exclusive but together offer a broader picture regarding the linguistic and cognitive effects subsequent to bilingual experience. These results once again reinforce the fact that the language domain is heavily influenced by cognitive control mechanisms. Furthermore, the thesis provides further important insights into how cognitive control mechanisms vary depending on the nature of task demands.

Clinical Implications

Although we have focused on informing bilingual models with the help of unimpaired data, this thesis also has important clinical implications for individuals with language impairment.

The bilinguals in Chapter 2 came from a social context where switching between two languages was a part of their everyday life. We have suggested that the language context drives the functioning of the cognitive control mechanisms. Assessment of cognitive control (executive functioning) abilities in speech pathology settings must consequently take this factor into account, especially during the assessment of bilingual aphasia. Equally important is for treatment studies on bilingual aphasia to consider whether treatment targeted at improving executive functioning may be appropriate considering the bilingual language context prior to stroke. Indeed it is rare for fine-tuned assessment of executive functioning to occur in clinical settings - this would seem vital for appropriate management and treatment of bilingual individuals with aphasia.

One of the main treatment goals for individuals with aphasia is to improve their ability to (re)acquire words to reduce communication breakdown. Results of novel word learning studies seem to suggest that the bilingual advantage in novel word learning is mediated by the efficient supervisory attentional control system. It would then indicate that, should assessment show impairment, treatment targeting this mechanism could improve general word (re)learning ability. However, this remains a hypothesis that should be a focus of future clinical research. Such research would not only have clinical implications but also further inform the interaction between language learning and supervisory attentional control system.

Summary and Future directions

The four experiments reported in this thesis provide important insights into the effects of bilingualism on three key areas of cognition and language – (i) processes at cognitive control level, (ii) sentence recognition processes, and (iii) mechanisms of word learning. The overall findings from our experiments provide further evidence for the interaction between bilingualism and cognitive control processes. The results also further reinforce the need to obtain data from bilingual communities and contexts that have not traditionally been studied. Our results also to indicate that a bilingual advantage is evident even for bilinguals from lower socio-economic status where bilingualism was not associated with a classroom or migrant status but rather an everyday living experience. Future studies must take this bilingual context into account when explaining the variability in data on bilingual (dis)advantages in processing. We suggest that the adaptive control hypothesis is a valuable account to guide such an endeavour. However, research is still needed to further test and refine this hypothesis, and, in particular, suggest that novel word learning is a potentially powerful methodology for such research.

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Appendix 1

MACQUARIE University

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HS Ethics application ref: 5201100891D - Final approval (Please ignore previous email)

FHS Ethics <fhs.ethics@mq.edu.au> Fri, Jan 13, 2012 at 8:53 AM

To: Katherine Demuth <katherine.demuth@mq.edu.au>, VISHNU KALEECKAL KRISHNANKUTTY NAIR <vishnu.kaleeckal-krishnanku@students.mq.edu.au>

Dear Professor Demuth,

Re: "Effects of bilingualism on novel word learning"

Thank you for your recent correspondence. Your response has addressed the issues raised by the Faculty of Human Sciences Human Research Ethics Sub-Committee and you may now commence your research.

The following personnel are authorised to conduct this research:

Mr Vishnu Kaleeckal Krishnankutty Nair
Prof Lyndsey Nickels
Professor Katherine Demuth

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).

2. Approval will be for a period of five (5) years subject to the provision of annual reports. Your first progress report is due on 12 January 2013.

If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:
http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Sub-Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the Sub-Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

5. Please notify the Sub-Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:

http://www.mq.edu.au/policy

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have final approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of Final Approval to an external organisation as evidence that you have Final Approval, please do not hesitate to contact the Ethics Secretariat at the address below.

Please retain a copy of this email as this is your official notification of final ethics approval.

Yours sincerely,

Dr Peter Roger
Chair
Faculty of Human Sciences Ethics Review Sub-Committee
Human Research Ethics Committee

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RE: HS Ethics Application - Final Report Approved (5201100891)

Fhs Ethics <fhs.ethics@mq.edu.au> Mon, Feb 2, 2015 at 11:51 AM
To: Professor Lyndsey Nickels <lyndsey.nickels@mq.edu.au>
Cc: Dr Britta Biedermann <britta.biedermann@mq.edu.au>, Mr Vishnu Kaleeckal Krishnankutty Nair <vishnu.kaleeckal-krishnanku@students.mq.edu.au>

Dear Prof Nickels,

Title of project: 'Effect of bilingualism on cognitive-linguistic abilities' (Ref: 5201100891)

FINAL REPORT APPROVED

Your final report has been received and approved, effective 2nd February 2015.

The Faculty of Human Sciences Human Research Ethics Sub-Committee is grateful for your cooperation and would like to wish you success in future research endeavours.

Yours sincerely,

Dr Anthony Miller
Chair
Faculty of Human Sciences
Human Research Ethics Sub-Committee

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