AN INQUIRY INTO BILINGUAL LANGUAGE CONTROL

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DECLARATION

I hereby declare that the thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

Seng Su Lin

29 August 2014

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Summary

The thesis is concerned with the nature of bilingual language control. By this, it is interested in understanding if the processes responsible for the bilingual ability to effortlessly switch between two languages (language control) are the same as that responsible for the smooth shifting of one task to another in everyday life (executive control). Findings of a performance advantage shown by bilingual children over monolingual children in tasks of executive control indicate an enhancement of cognitive ability related to being bilingual, and compel researchers to believe that there is little distinction between the two control processes. This view is however undermined by the lack of evidence in two areas: Young adult bilinguals have not been examined for such a bilingual advantage and there is no evidence to show that the bilingual advantage in executive control originates from bilingualism. The first part of the thesis deals with this. Another issue is whether or not bilinguals show an advantage in executive control does not in itself reveal if executive processes are involved in bilingual language processing. A way to approach this is to compare the time costs involved when bilinguals switch between two languages (language switching) versus those incurred when individuals switch between two non-language tasks (task switching). The rationale is that if there are no significant differences between language switching and task switching, it is likely that bilingual language control is subserved by general cognitive mechanisms. However, the dearth of research investigating executive control patterns in language switching, as well as a methodological confound related to cue stimuli in language switching paradigm, question the validity of prior language switching research. The second part of the thesis confronts this dearth and examines previously unexplored bilingual language switching behaviour through a novel, unconfounded, language switching paradigm. In general, no bilingual advantage was found in tasks of executive or language control. Task switching patterns associated with executive control were not replicated in language switching experiments. These results challenge the view that bilinguals use executive control to mediate bilingual language processing.

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CHAPTER 1 – THESIS OVERVIEW

In managing two languages, bilinguals must switch from one language to another as well as depend on the control processes that help them manage two languages in different communicative contexts. Parallels have been drawn between the control processes bilinguals use to selectively access words from a choice of two languages and the executive processes humans use in general to react to dynamic situations in their everyday environment. The broad claim is that language control is not a unique human function and is therefore not different from executive control (Bialystok, Craik, Klein, and Viswanathan, 2004; Meuter and Allport, 1999).

This claim is based on findings in two areas of research, *the bilingual advantage* and *language switching.* In the rest of this section, we summarise the problems associated with the findings in each field and how these weaken the main claim. Our experiments were designed to deal with these problems.

In work done on the bilingual advantage, previous research has shown that bilingual children resolve interfering information better than monolingual children in language tasks (Ben-Zeev, 1977; Galambos and Hakuta, 1988; Ianco-Worrall, 1972) and in non-language tasks (Bialystok & Codd, 1997; Bialystok & Majumder, 1998). There is also evidence that shows that even when only one language is used, a bilingual's second language is active (Hermans, Bongaerts, de Bot, & Schreuder, 1998; Rodriguez-Fornells et al., 2005). Bilinguals then must constantly be controlling their languages to suppress unwanted information from the irrelevant language. Researchers believe that it is this experience of managing an extra language that is responsible for the advantage seen in bilingual children (Bialystok et al., 2004; Emmorey, Luk, Pyers, & Bialystok, 2008). In managing an extra language, bilinguals amass practice at using the processes involved in executive control via the constant need to attend to a relevant representation, particularly under misleading contexts (Bialystok, 2007). A central model in this research is the Inhibitory Control (IC) model (Green, 1998). This model specifies that it is the inhibitory component of executive control, the Supervisory Attentional System (SAS), that is responsible for suppressing possible interference from competing words in the target language, as well as the non-target language. Since the SAS was originally conceived to explain how humans might suppress inappropriate behaviour in the real world (Norman & Shallice, 1986), in adopting the SAS to explain language behaviour, the Inhibitory Control model assumes no differences between language control and executive control. It therefore provides the theoretical basis on which to explain the bilingual advantage: Bilinguals are better than monolinguals at suppressing interference because they constantly practice this very skill when they use two languages.

There are however crucial issues related to this bilingual advantage that have not been addressed. One of these issues is that findings on the bilingual advantage using standardized experimental paradigms designed to examine the executive control of interference have been inconsistent. A bilingual advantage has been replicated in older adults using these tasks (Bialystok et al., 2004), but this effect appears to be more elusive in younger adults or children (Bialystok, Luk, & Craik, 2008a; Emmorey et al., 2008). An accidental finding that bilinguals actually show an advantage in trials without interference (Emmorey et al., 2008) further adds to the complexity of the issue – do bilinguals have an advantage at resolving interference or not because of their language experience?

Another issue that has yet to be addressed is whether the underlying assumption that bilinguals are actually superior at language interference tasks – enhanced especially by having to constantly suppress whichever of their two languages is not relevant – is correct. For example, it has been noted that enhanced (non-language) suppression may develop from experiences other than bilingualism (Bialystok, 2006). Another way to put this is: if the bilingual advantage in the non-language domain is said to be the result of constant control over two languages then bilinguals should show superior control of language interference as well. However to date there has been no study demonstrating this is actually the case. These various unaddressed issues raise questions about the idea of a bilingual advantage. Without empirical evidence showing that it is the very experience of continually suppressing the irrelevant language that leads to the enhancement of the control of interference, the premise of the bilingual advantage is in question, as well as the theoretical foundation of the IC model.

This issue is taken up in Experiments 1 and 2 in the thesis. Experiment 1 examined the bilingual advantage by testing 12 monolinguals and 12 bilinguals on a modified flanker task. In order to examine if the experience of being bilingual led to enhanced skills of resolving language interference, Experiment 2 tested a new group of 12 monolinguals and 12 bilinguals on a novel picture-word interference task. All participants were undergraduates.

The SAS component in the IC model not only controls interference at the level of word representations, it also exerts control at the level of completing a series of simple, different tasks. For example, everyday life requires that bilinguals switch between their two languages in bilingual discourse. Although this appears to be effortlessly carried out, when examined under controlled settings, bilinguals suffer from intrusions of the unwanted language (Costa, Caramazza, & Sebastian-Galles, 2000; Hermans et al., 1998). The SAS, which in suppressing inappropriate behaviour is responsible for ensuring that people switch smoothly from one cognitive episode to the next (Norman & Shallice, 1986), is proposed to also govern the fluent switching from one language to another (Green, 1998).

From the above account, another way of examining the connection between language control and executive control is to explore language switching patterns and compare them with established task (executive) switching patterns. A central construct in this research is the *switch cost*. The switch cost is related to the observation that when participants are required to shift frequently among a set of simple tasks, they tend to respond more slowly immediately after a task switch, than when they repeat the same task. Thus, the switch cost is taken to be a measure of how well participants are able to control the ability to change a task: the larger the switch cost, the more difficult it is to make a switch. By examining the behaviour of this construct, researchers are able to infer something about the mental processes that enable a task switch. This is done through the cued task switching method which involves presenting participants a series of stimuli, each preceded by a cue. The cue may indicate for the same task to be carried out again, or it could indicate a change in task. The majority of task switching studies employ this method, or a variant of it, to examine how people manage shifting between two cognitive tasks (e.g., Allport, Styles, & Hsieh, 1994; see Kiesel et al., 2010).

A finding of interest in task switching research is that participants tend to take more time to switch into an easier task compared with switching into a harder task (Allport et al., 1994; Yeung & Monsell, 2003). This asymmetry of switch costs has also been observed in language switch research, where bilinguals take longer to switch to their stronger language than they do to switch to their weaker language (Jackson, Swainson, Cunnington, & Jackson, 2001; Meuter & Allport, 1999), thus strengthening language switch researchers' belief that language control is the same as executive control. It has been suggested that the switch cost asymmetry reflects a need for greater suppression of the first language (L1) when using the second language (L2), which makes later switching back to L1 more costly. Therefore, common patterns of switch cost asymmetry across language switching and task switching studies form an important piece of evidence supporting the IC model. There is, however, a problem associated with this pattern of switch cost.

An extension of the logic that an unused language is suppressed according to how strong it is, is that bilinguals who are equally proficient in two languages (balanced bilinguals) should experience equal amounts of suppression applied to each language when the other is being used. They should then show symmetrical, and not asymmetrical, switch costs. Studies confirmed this pattern of symmetry when balanced bilinguals took the same amount of time to switch between L1 and L2 (Costa & Santesteban, 2004). However, when tasked to switch between L1 and their weak third language (L3), balanced bilinguals too showed symmetrical switch costs, suggesting that the weaker, less proficient language may not always be differently suppressed from the stronger, more proficient language (Calabria, Hernandez, Branzi, & Costa, 2012; Costa, Santesteban, & Ivanova, 2006).

In addition to this problem, a general criticism that may be raised against language switching research is the dearth of investigations exploring other viable, important patterns of switch costs that have long been studied by the task switching community. This can be narrowed down to two task switch theories: *task set inertia* and *task set reconfiguration*.

An aspect of task set inertia theory states that switch costs reflect activation from a preceding trial persisting into the present trial and which interferes with switching to a new task (Allport et al., 1994). However, this activation dissipates over time and as the task (different from the one in the preceding trial) in an upcoming trial is delayed, switching performance improves. Support for this theory has come from research showing that by prolonging the duration immediately after completing a task, participants are quicker at accomplishing a task switch on the next trial than when the duration is shorter (Meiran, Chorev, & Sapir, 2000). Evidence for the dissipation of a "task set" – the organisation of metal processes required for a particular task – is indexed by a reduction of switch costs as the next task switch is delayed.

Task set reconfiguration theory on the other hand states that switch costs reflect the time taken to configure participants' mental settings before the next task switch can be executed (Monsell, 2003). What exactly is being configured is not clear, but task switch researchers believe that it is a combination of task-specific processes such as attending to task-relevant information, or setting up a new goal for the next task (Monsell, 2003; Rogers & Monsell, 1995). The prediction this view makes is that if participants are allowed adequate time to prepare for a change in task, then this should reduce their switch cost. In other words, task set reconfiguration suggests that as the stimulus for the next task switch is delayed, participants will experience a reduction in switch costs. Therefore, while switch costs are a reflection of the ability to actively prepare for a new task according to task set reconfiguration, in task set inertia, they reflect the ability to overcome persistent interference from a completed task.

A problem with the predictions of task set inertia and task set reconfiguration is that they both have the same outcome – a reduction in switch costs as the next task switch is delayed – but describe very different processes. To tease apart the contributions of each theory in accounting for switch costs, Meiran et al. (2000) used the experimental cue to divide the duration of one trial into a pre-cue and a post-cue interval. Any persisting activation from a previous trial would then be carried over to the pre-cue interval, and since participants could begin preparing only after the cue was presented, reconfiguration processes were confined to the post-cue interval. This novel study demonstrated, with preparation time held constant, a reduction in switch costs as the pre-cue interval lengthened. It also showed that, with dissipating time held constant, switch costs reduced as the post-cue interval lengthened.

Examining task set inertia and task set reconfiguration in language switching promises insight into what goes on before or after the language cue, and can potentially provide some answers as to whether language control operates within the domain of executive control. However, in contrast to the advances made in task switch research, the same progress cannot be said of language switching research. No effort to our knowledge has been made to understand what basic reconfiguration or dissipation processes occur in a language switch. A final issue stems from the lack of attention given to the cued language switching method that has been extensively used in the field, but which has not been properly validated.

Logan and Bundesen (2003) questioned the validity of the cued paradigm. They reasoned that each time a task switches, the cue preceding the stimulus must also switch. Since cue switches accompany task switches, switch costs may actually reflect the changes associated with a cue switch, and not a task switch. If this is true, then it could potentially undermine all of task switch research. Monsell and Mizon (2006) stepped up to defend the task switching method and showed that with careful consideration of possible confounds, the procedure can be a reliable tool to examine executive control. Task switch evidence in support of Monsell and Mizon’s work has surfaced (Altmann, 2006) but other data showing that task switch data can indeed reflect cue switches (Arrington & Logan, 2004) strongly suggests that research involved in task- or language switching should adopt procedures that control for cue switch effects.

The above problems highlight a need firstly to eliminate confounds occurring in the language switching experimental set-up before proceeding to examine the control processes involved in language switching. In view of this, Experiments 3A, 3B, and 4 carry out three language switching picture-naming studies that novelly employ a method to isolate “true” language switching effects from cue-switch effects (Logan & Bundesen, 2003; Monsell & Mizon, 2006). To respond to the gap in language switching literature with respect to task set reconfiguration and task set inertia, Experiments 3A and 3B examine if language switch costs reduce during the post-cue interval, and Experiment 4 examines if the same behaviour can be observed during the pre-cue interval. Throughout these three experiments, we also examine if patterns of language switch cost asymmetry or symmetry hold as predicted by the IC model. 12 unbalanced bilinguals and 12 balanced bilinguals performed Experiments 3A and 3B, and a new group of 12 unbalanced bilinguals and 12 balanced bilinguals were recruited for Experiment 4. All participants were undergraduates.

Research Aims

In summary, this thesis builds on existing work to move the general field of bilingual language control beyond familiar methods of investigation, while being grounded in theories of bilingual language production and executive control. It aims to show that if bilinguals have an advantage in executive processes over monolinguals, and if language switching patterns, after taking into account cue confounds, are behaviourally not different from task switching patterns, then it is likely that bilinguals control their languages through executive processes.

Thesis Structure

The three-part literature review is presented in Chapters 2, 3, and 4. In Chapter 2, concepts central to the IC model are introduced. These are the structure of the bilingual lexicon, the joint activation of languages, and executive control. The IC model is introduced towards the end of Chapter 2 which concludes with the implications the model has for research on the bilingual advantage and language switching. Chapter 3 reviews the literature on the bilingual advantage. It provides the literature showing the evidence for it but questions the generalizability of the phenomenon. Chapter 4 moves into the field of language switching.

The chapter begins with the groundwork of task switching to serve as a framework for reviewing the research on asymmetrical switch costs, task set inertia, and task set reconfiguration. The latter half of the chapter raises the issue of cue-switch effects in task switching and the implications this has for language switching research. Chapter 4 concludes with future directions for language switching research. Chapters 5 to 8 are four experimental chapters that examine the issues raised above. Chapter 9 discusses the results of the experiments within the claim that was investigated – whether language control is executive control – and concludes with the limitations of the research and possible future directions.

CHAPTER 2 – LANGUAGE CONTROL

Overview

Bilingual language control refers to the mental linguistic processes that are responsible for choosing words from one of two languages during bilingual discourse. A problem that preoccupies researchers in this area is explicating how these mental linguistic processes relate to general non-linguistic processes that govern human action. In discussing this body of work, the chapter provides an outline of the research that has contributed to a dominant model of the bilingual lexicon, the Revised Hierarchy Model. It then briefly reviews studies examining cross language interference phenomena. In the latter half of the chapter, two views addressing the phenomenon are advanced, the language specific view and the other is the Inhibitory Control model. Given the central role this model plays in the thesis, we provide its formal details and how it implements non-linguistic processes in accounting for bilingual language control. The chapter concludes with implications and predictions of the model.

The Problem

There exists in any speaker of a particular language, a complex linguistic system that enables fluent speech. How speech production takes place is not yet fully understood, but at least three levels of representations have been proposed to characterise this process (e.g., Poulisse & Bongaerts 1994, in Kroll, Bobb, Misra, & Guo, 2008). At the first level are concepts. Here is a vast store of non-linguistic multimodal ideas, shaped by an individual's culture and experience (Francis, 2005; Pavlenko, 1999). Each concept is also referred to as a semantic or mental representation. At the second level are concepts represented in words which accumulate to form an individual’s lexicon. Pavlenko (1999) notes that words not only carry with them orthographic information, but also details on how they relate to other words, as well as conceptual information cascaded from the preceding level. Finally, at the third level are words represented in their phonological form. For meaningful speech production to take place, these levels have to be controlled by higher processes of conceptualizing, formulating, articulating, and self-monitoring (Levelt, 1989). Speaking in one language then undoubtedly involves a rich linguistic system interacting across all levels.

Consider now fluent bilinguals who possess not one, but two systems of linguistic knowledge, both equally rich and detailed. Unlike monolinguals, they are faced with possible interference from another potentially competing language system. How might bilinguals choose words from one language while avoiding interference from the other language? Aside from exercising control across levels of the production process, they require a mechanism to also control an additional, fully elaborated language system. An understanding of how two language systems might be represented in the bilingual lexicon may lend some insight – if the languages were structurally separate then selection can be confined to one system.

The Bilingual Lexicon

In one of the earliest models of the bilingual lexicon, Weinreich (1953, in de Groot, 2011) proposed a compound-coordinate dimension which described three types of bilinguals. On the compound end were bilinguals who acquired meanings that were shared between two languages, but the forms of meanings were language-specific. On the coordinate end were bilinguals whose meanings and forms of one language were separate from those of the other language. In between these two types were subordinate bilinguals for whom forms in the weaker language were linked to their translations in the stronger language. Over time, as the weaker language developed, this link would receive less support from the stronger language, and subordinate bilinguals would shift towards compound bilingualism. Thus, in this model, there were three primary components: a store of meanings (concepts), a store of first language (L1) forms, and a store of second language (L2) forms. Through one conceptual store that was directly linked to two languages, compound bilinguals could rapidly access any word in either language. In contrast, coordinate bilinguals who acquired a different semantic representation for each word in each language had to navigate two conceptual stores, which made access slow and error-prone (Figure 1).

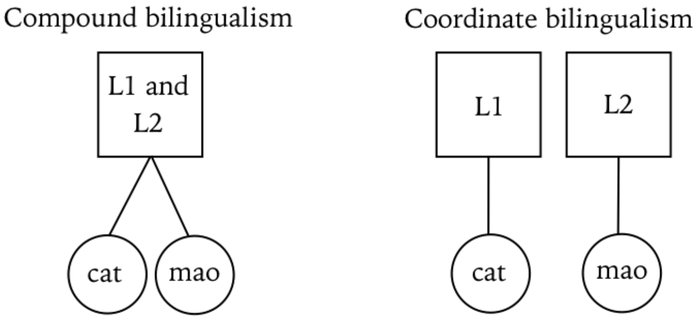


Figure 1: Weinreich's model of bilingualism (adapted from Woutersen, Cox, Weltens & de Bot, 1994). In the figure above, the first language (L1) is English and second language (L2) is Mandarin. Compound bilingualism results in a common underlying conceptual representation for both 'cat' and 'mao', while this remains separate in coordinate bilingualism.

Weinreich's contribution in theorizing a store of non-linguistic meanings that was separate from the word forms of each language afforded a basic description of bilinguals, but the approach failed to explain how connections among the three components supported the selection process.

The emergence of hierarchical models (e.g., Kroll & Stewart, 1994; Potter, So, Von Eckardt, & Feldman, 1984) ushered in a new approach to modelling bilingual language processing. These models not only focused on how each component was linked, but also addressed the extent that representations at each level were integrated (e.g., Grosjean, 2008; Heredia, 1997; Kroll & Stewart, 1994). Related to this, a particularly fruitful area of research was the examination of bilinguals with a weak language. Since this group of bilinguals, also called unbalanced bilinguals, were assumed to require support for L2 access that was not necessary for L1 access, an asymmetry could be expected between L1 and L2 performance. This made them suitable for testing empirical predictions, the results of which could shed light on how L1 or L2 word forms were differently related to concepts.

Based on Weinreich's (1953, in de Groot, 2011) suggestion that meaning was separate from word forms, Potter et al. (1984) hypothesized that L2 words could be directly linked to concepts. Alternatively, they could be mediated by L1 in which case a concept would first be retrieved in L1, and then translated to L2 for output. This could be tested in the following way. If, when naming a picture in L2, a concept was directly accessed, then this task would be carried out more quickly than translating a word from L1 to L2. If however translating to L2 was faster than naming a picture in L2, then L2 words were accessed through L1 for production (Figure 2). Potter et al. called the process of accessing L2 directly from concepts the *concept mediation hypothesis*, and the method by L1 mediation the *word association hypothesis.*

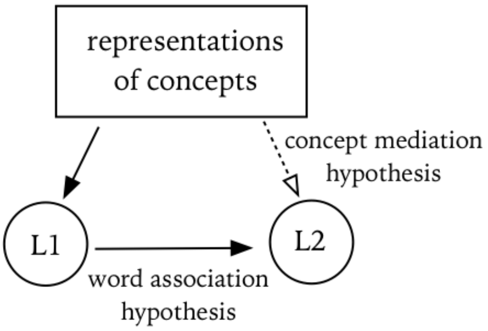


Figure 2: Two different routes for second language (L2) processing (adapted from Potter et al., 1984). L2 concepts are processed through the mediation of first language (L1) words (word association hypothesis, bold arrows), or through a direct link to concepts (concept mediation hypothesis, dotted arrow).

Based on the result that both balanced and unbalanced bilinguals generated lower reaction times in L2 picture-naming than L1 to L2 translation, the authors rejected that L1 played a role in L2 retrieval. They concluded that regardless of L2 proficiency, L1 and L2 were conceptually processed. Note that this description is similar to Weinreich's original proposal, and does not get us far in elucidating the nature of the bilingual selection process. Besides, Potter et al. were testing two distinct language skills, one of translating which required selecting a word amongst others under consideration, and another of picture-naming which emphasized the identification of an object's attributes. This difference had the potential to confound reaction time data. Nevertheless, what Potter et al. managed to show was that empirical results of L1 and L2 performance could reveal the structure of the lexicon.

Contrary to the findings of Potter et al. (1984), subsequent bilingual translation studies (Kroll & Stewart, 1994; Sanchez-Casas, Davis, & Garcia-Albea, 1992) found that bilinguals show an asymmetry in their L2 processing, suggesting a difference in the way L1 and L2 are linked to concepts. Specifically, unbalanced bilinguals were shown to translate L2 words to L1 more quickly than they were to translate L1 words to L2. A processing sensitivity to L2 proficiency levels was also demonstrated: The more dominant bilinguals were in their L1, the higher the probability they would translate more quickly into L1. These findings highlighted the need for a model of the bilingual lexicon that would take into account the different proficiency levels of each language in a way that more closely represented real-life bilingualism.

The Revised Hierarchical Model (RHM)

In view of this need, Kroll and Stewart (1994) combined the earlier hypotheses of Potter et al. (1984) and proposed the Revised Hierarchy Model (RHM). In their model, both L1 and L2 are interconnected, and both languages can access the conceptual store directly. However, transmission of information is limited to the strength and directional flow of each link. In fluent bilinguals, *conceptual links* and *lexical links* are strong, and information flows freely between each component (Figure 3). This would explain their expert use of two languages, but for unbalanced bilinguals, this is not the case. The L2 conceptual link for this group of bilinguals is weak and does not facilitate L2 naming of concepts. Similarly, drawing an L2 word from its L1 word form is weakly supported, making translating from L1 to L2 difficult. However, due to established word knowledge and vocabulary in L1, it is likely that each L2 word form is easily mapped to an L1 word form, making translating from L2 to L1 straightforward.

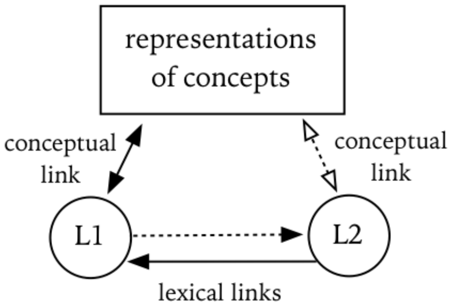


Figure 3: The Revised Hierarchy Model (adapted from Kroll and Stewart, 1994). The diagram above depicts the representation of an unbalanced bilingual's lexicon and the direction of routes of access to each language. Links with the L1 are strong (bold arrows) while links with the L2 are weak (dotted arrows).

Take for example the profile of typical unbalanced Singaporean English-Mandarin bilinguals. They are fluent in English, but have a weak proficiency in Mandarin. Upon having the intention to produce a word in English, the English conceptual link is activated. This connection is robust, and is reflected by fluent English production. When speaking in Mandarin, production begins similarly by activating the intended concept. Transmission of information then proceeds two ways. The bilinguals access, with some difficulty through the Mandarin conceptual link, the Mandarin target word form, but at the same time receive additional support through activated lexical links which transmit information over from the translated English word form. This flow of information is depicted in Figure 3 (dotted lines). As they gain proficiency in Mandarin, the Mandarin conceptual link is strengthened, and the reliance on the English lexical link is reduced. Eventually, they may function the way balanced bilinguals do, by directly tapping into concepts without support from lexical links.

The RHM asserts that unbalanced bilinguals pay more attention to L1 word forms in order to support L2 word selection, but that balanced bilinguals attend immediately to the concepts of words, irrespective of the language of response. It also hypothesizes that unbalanced bilinguals, by exploiting a strong L2 to L1 connection, will translate words more quickly from L2 to L1, than vice versa. The RHM has enjoyed considerable support from studies demonstrating unbalanced bilinguals experiencing interference from orthographically or phonologically similar L1 words during L2 production (Ferre, Sanchez-Casas, & Guasch, 2006; Kroll, Michael, Tokowicz, & Dufour, 2002; Talamas, Kroll, & Dufour, 1999) and quicker translation latencies for L2 to L1, than L1 to L2 (Kroll & Stewart, 1994; Sanchez-Casas et al., 1992) although not all data have been consistent. For example, the translation asymmetry between L1 and L2 is not always replicated (De Groot, Dannenberg, & Van Hell, 1994; Van Hell & De Groot, 1998), with some studies showing that unbalanced bilinguals are able to translate from L1 to L2 more quickly than from L2 to L1 (De Groot & Poot, 1997; Duyck & Brysbaert, 2004).

Despite some difficulty with characterising lexical links, in all these studies, it is implicitly acknowledged that the conceptual links proposed by Kroll & Stewart (1994) hold.

This aspect of the model suffices for Green (1998) whose model of Inhibitory Control is introduced at the end of this chapter. For now, we turn to the difficulty of understanding the nature of lexical links. Essentially, lexical links represent the level at which word forms between two languages interact. The difficulty appears to stem from deciding whether it is L1 or L2 words that are more easily accessed. As the following sections will show, this problem is related to L1 and L2 words being in constant competition, and that there is no straightforward way to describe L1 and L2 access.

In the next section we outline the basic speech production process in greater detail than before and review studies that have focused on the selection of L1 and L2 word forms. This is followed by two views that have sought to describe bilingual language control, the language-specific view and the language-nonspecific view (Inhibitory Control model).

Two Active Languages

A prerequisite to examining how word forms behave is the need to provide a basic landscape of how they might be represented in a model. To this end, and following Bock and Levelt (1994), we refer to word forms as "lemmas", and retain the term *lexical* (e.g., lexical level, lexical retrieval etc.) to describe operations associated with them. Bock and Levelt describe lemmas as an abstract, preverbal word form. It may be said that unbalanced bilinguals have fewer lemmas in their L2 than their L1 lexicon. To distinguish what is and is not available for selection, lemmas are theorized to receive activation from conceptual access procedures, where the higher the level of activation of the lemma, the greater its availability, and therefore the better its probability of getting selected from amongst competing lemmas (Costa, 2005; Lupker, 1979).

A sketch of the basic monolingual speech production process then begins with an activated concept. Activations of other meanings related to the central concept are also activated to some degree (Collins & Loftus, 1975). A checking mechanism ensures that only activated concepts that are correctly linked to their lemmas carry activation down to the lexical level (Roelofs, 1992). At this point, a selection mechanism picks out the lexical candidate with the highest activation before proceeding to sequence a phonological output plan. Views regarding how lemmas exactly express their semantic and syntactic properties vary (see Caramazza, 1997), but this basic selection process of activation flow from the conceptual level to the phonological level is a widely accepted one (Collins & Loftus, 1975; Green, 1998; La Heij, 2005; Roelofs, 1992). Figure 4 on the next page illustrates this process. In the case of bilinguals however, for each concept that is activated, a corresponding lemma in the other language is activated too (Figure 5, page 18). Selection by the highest activated lemma does not work for this model of lexical access.

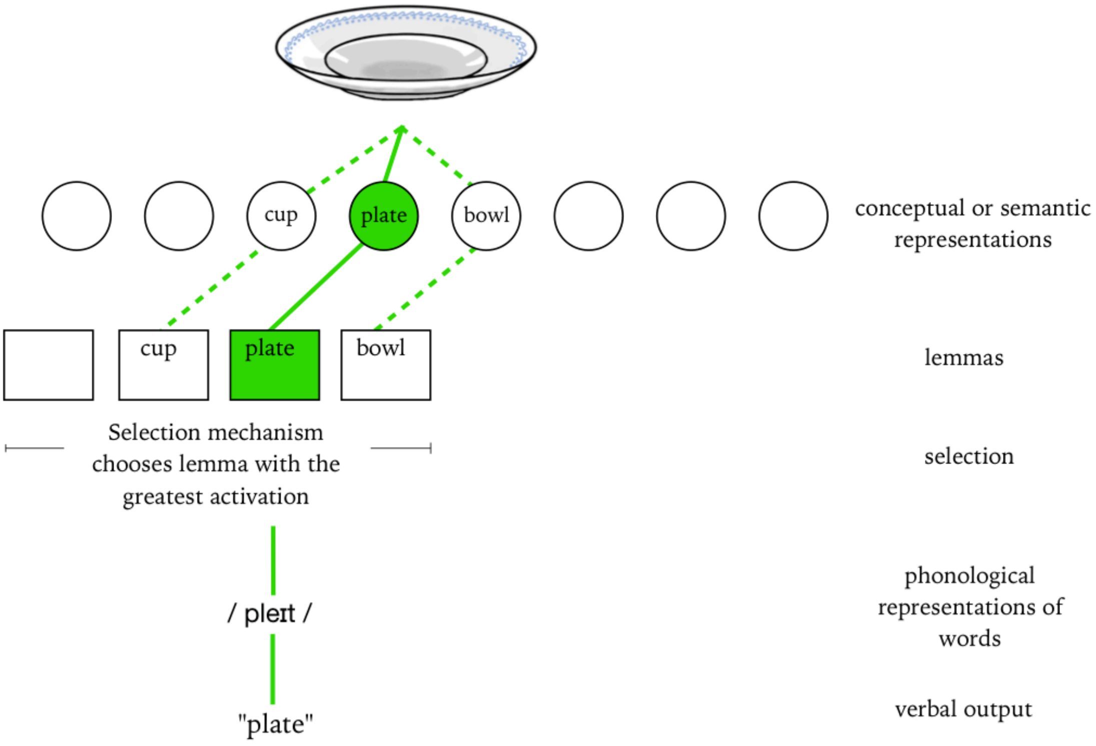


Figure 4: A model of lexical access by activation flow. Retrieving the item ‘plate’ triggers a spread of activation to related semantic representations (dotted lines). Activation then flows to the lemma level. The lemma ‘plate’ (bold lines) is the most highly activated lemma and is thus selected for output.

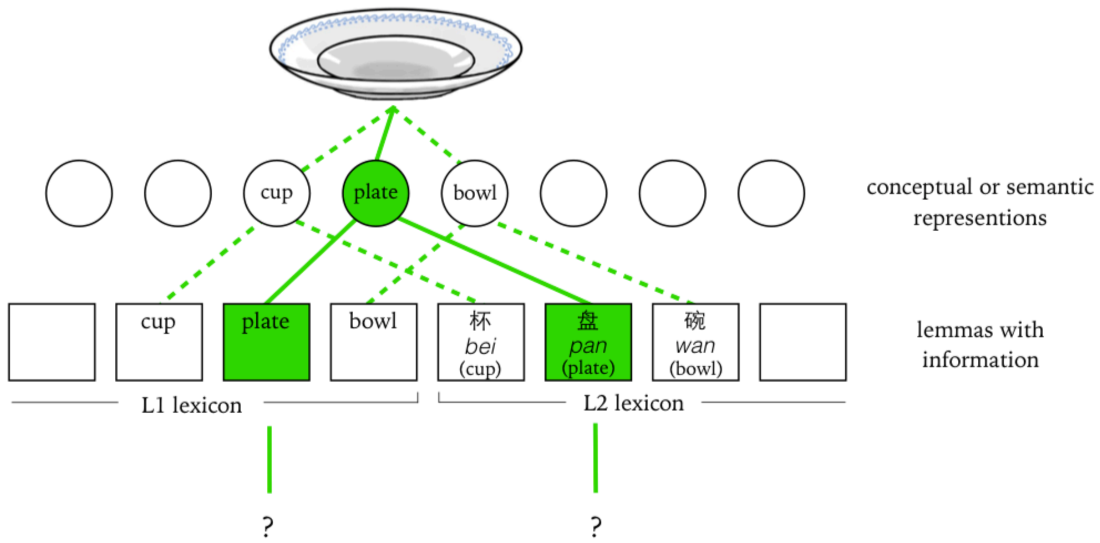


Figure 5: A schematic of spreading activation to two equally activated lemmas, 'plate' (L1) and 'pan' (plate, in Mandarin) (L2) in bilinguals who are equally proficient in English and Mandarin. How one lemma is selected from another equally activated lemma is still not clear.

In accessing the concept *plate,* how might bilinguals select *plate* over *pan* (plate, in Mandarin), given that both lemmas are equally activated? The logical possibility is that the lexicon of bilinguals is organised into two independent language-specific lemma stores as was once conceived by Weinreich (1953, in de Groot, 2011), without the need for proposed lexical links between languages (Kroll & Stewart, 1994) to typify bilingual language production. For instance, an English-Malay bilingual ordering a bowl of curry in English has no reason to mentally reconstruct the order in Malay, and an English-Tamil bilingual stall attendant responding to this order in English is unlikely to consider the response in Tamil. This makes selecting the correct language, and the intended lemma in that language, accountable by activation levels. It is an intuitive, and orderly way for accounting for bilingual lexical selection. However, there is evidence indicating a more complicated picture.

Researchers using different methods to tap into bilingual lexical access found that a bilingual's two languages were active even though only one language might be in production (Costa, Miozzo, & Caramazza, 1999; Hermans et al.,1998). One of these methods was using the bilingual picture-word interference (PWI) task. In this task, bilinguals were presented with a picture to be named in L1 that was accompanied by a L2 distractor word superimposed on the picture. The distractor might be phonologically or semantically related or unrelated to the picture name. Since unrelated L2 distractors bore no relation to the picture name, they were not expected to affect picture-naming in L1. Related L2 distractors on the other hand, had common lexical properties to the picture name, but were not part of the L1 lexicon. If picture-naming in L1 was affected by related L2 distractors, then, just as Weinreich (1953, in de Groot, 2011) and Kroll and Stewart (1994) had earlier hypothesized, there was some integration of representations at the lexical level.

The finding in these studies was that L1 picture-naming was affected when L2 distractors were phonologically similar to the picture name (Costa et al., 2000; Hermans et al. 1998) or semantically related to the picture name (Caramazza & Costa, 2000). In a lexical decision task where bilinguals had to decide whether a string of letters was a word in L1, they took longer to make a decision if the L1 word had the same form in L2, albeit with a different meaning. For example, Dutch-English bilinguals took a longer time to decide that the Dutch word *kind* (meaning *child*) was a word because it had the same word form as the English word that means *understanding* (van Heuvan, Schriefers, Dijkstra, & Hagoort, 2008). In yet another task type, the bilingual Stroop task, bilinguals took a longer time to name the colour of a word in L1 if it was printed in a conflicting colour name in L2, than if the word was printed in a congruent colour name in L2 (Chen & Ho, 1986; Gerhand, Deregowski, & McAllister, 1995). In all these cases, the non-target language did not seem to go “offline”. Regardless of the language demanded in a particular context, bilinguals appeared to be constantly open to interference from the unused language. This cross language interference suggested that bilinguals suffered intrusions from their other language during speech production. However, anecdotal observations instead demonstrated the remarkable ability to select words with great accuracy. Bilinguals then had to have a selection mechanism that was able to handle lexical competition from target lemmas.

Costa et al. (1999) suggested that lemmas entered a *language-specific* selection process. Even though lemmas across two languages were activated, the selection mechanism was “blind” to lemmas which were not from the target language. Green (1998) disagreed and believed that selection was *language-nonspecific*. Instead of being ignored, unsuitable lemmas were inhibited by the same mechanism that inhibited inappropriate non-language behaviour. Therefore, in one view, selection appeared to be a purely linguistic process where selection acted on only the relevant language, while in the other, selection was sensitive to both languages and was part of executive function.

Language Specific Selection

The bilingual PWI task offered a good opportunity to test these two hypotheses. If naming a picture in L1 was delayed in the presence of a L2 distractor, then it was likely that L2 lemmas interfered in the L1 selection process, rendering the language-specific view improbable. In fact, as discussed in the preceding section, cross language interference effects had been observed in a number of studies (Hermans et al., 1998; van Heuven et al., 2008), indirectly giving support to the language-nonspecific view (although this evidence did not allow one to conclude if the selection originated from executive sources). However, Costa et al. (1999) argued against interpreting such evidence as support for the language-nonspecific view. Explaining how a language-specific model could account for cross language interference, they pointed out that the lemma triggered by an L2 distractor would activate its corresponding lemma in the L1. Therefore, even if L1 naming times were slower on trials with related L2 distractors, it was possible that the source of interference was the L1 lemma counterpart of the L2 lemma distractor. In this way, selection and interference were confined to the lexicon of one language and thus remained language-specific.

A more telling PWI condition would be to have a distractor that was the L2 translation of the L1 picture name. Consider the bilingual PWI stimulus of the picture of a cat to be named in English with L2 distractor *mao* (“cat”, in Mandarin). The picture and distractor share the same conceptual representation and primary activation spreads to two main lemmas, *cat* and *mao*. It is likely that secondary activation also spreads to related lemmas such as *dog* and *gou* (“dog”, in Mandarin), but *mao* remains the strongest competitor to *cat*, having been triggered directly by the distractor. Costa et al. (1999) argued that if the selection mechanism did not consider L2 competitors, then responding in L1 should not be delayed even if the L2 distractor was the translation of the target. At the same time, *mao* would supply additional activation to its corresponding L1 lemma, *cat*. This would further increase the activation level of the lemma *cat*, and therefore selection of this lemma should be *faster* than when the L2 distractor was unrelated.

Costa et al. (1999) tested balanced Catalan-Spanish bilinguals who were tasked with naming pictures in Catalan accompanied by Spanish distractors. There were three distractor conditions, related, unrelated, and “identity”. In the identity condition, the distractor was the Spanish translation of the picture name in Catalan. As expected, unrelated distractors did not influence naming speed while related distractors delayed naming speed. In the critical identity condition, as the researchers had predicted, naming was faster compared with the unrelated condition. Costa and Caramazza (1999) followed this up with a study on two groups of unbalanced bilinguals with different proficiencies in English and Spanish. In one group, Spanish-English bilinguals were dominant in Spanish, and in the other, English-Spanish bilinguals were weaker in Spanish. Using the same experimental conditions as the previous study, Costa and Caramazza tested these two groups with naming pictures in Spanish and printed distractors in English. If results of Costa et al. showing facilitation under the identity condition were reliable, then regardless of Spanish proficiency, bilinguals should experience facilitative effects in the identity condition despite potential interference from English distractors. True enough, the facilitative effect of an identity distractor was replicated and the researchers concluded that even though both languages were active, only the lexical items in one language were in competition, and therefore the lexical selection was language-specific.

Evidence for a language-specific view has mainly come from these two studies. While the findings can be interpreted as Costa et al. (1999) and Costa and Caramazza (1999) have, there has been no further replication of the identity effect in other groups of bilinguals. More seriously, there is no theoretical basis to claim that a selection mechanism should ignore the lemmas of an irrelevant language. In contrast to the language-specific view, the language-nonspecific account is represented by the relatively elaborate Inhibitory Control (IC) model (Green, 1998), and is backed by an influential theory of executive control.

In the final section of this chapter, we describe the IC model. The section begins with an introduction on executive control.

Executive Control

Researchers often use *executive control* as an umbrella term to refer to the cognitive processes responsible for the mental control of one's behaviour in adaptive situations (e.g., Shallice, Burgess, Schon, & Baxter, 1989; Wagner, Bunge, & Badre, 2009). The term is used interchangeably with *executive function, cognitive control*, *task control*, or *control processes*. Typically, if a component of executive control is referred to, for instance the ability to focus on a stimulus attribute (executive attention), or the ability to suppress inappropriate behaviour (executive inhibition), each of these components may be loosely indicated as *executive processing*. In a way, the varied ways of describing executive control reflects its nebulous nature since there is no single behaviour that can be tied to it. For instance, speech-impaired patients clearly suffer from a language disorder, but it is not exactly clear what patients with executive dysfunction are impaired in. For this reason, it has been helpful for researchers to conceptualize executive control as an orchestration of discrete processes that generate appropriate behaviour(s) in the real world.

Take for example a driver who notices that he is headed for a traffic jam. He can choose to carry on the same route, or to take a detour. While deliberating his choices, he has to navigate traffic, steer the wheel, and monitor his position in relation to other drivers on the road. If he decides to detour, he has to continue negotiating traffic, assess road conditions, recall and compile possible destinations, locate possible exit roads, and so on. Each of these steps, whether triggered by an external source (traffic conditions) or generated by an internal intention (deciding to detour), requires initiating executive control to coordinate an appropriate response. Norman and Shallice's (1986) theory of executive control was proposed to account for human behaviour such as the one above. Two aspects of the model, schema selection and schema supervision, are relevant to the IC model.

Schema management

The Norman and Shallice model (Norman & Shallice, 1986) describes two kinds of actions, routinized actions that are highly practiced, and willed actions that usually occur in novel situations. Each routine action is a *schema.* Schemas represent generic knowledge connected with an action or thought that are modified along with life's experiences, and range from being of a higher order (e.g., problem-solving) to a lower order (e.g., pointing). Schemas can cooperate to give rise to complex behaviour, but one schema may override another if it becomes more relevant to the task goal. For instance, a member of a meeting in session could possibly activate a set of schemas to guide his behaviour; these may include listening, speaking, or taking turns at responding. Depending on which schemas are most task-relevant (e.g., listening to a question directed at him), less relevant ones (e.g., responding) are inhibited. In general, the manner in which schemas are regulated could be said to be well-practiced since schemas can appear to be automatic to the point that one can carry out error-free actions without thinking too much about them.

The Supervisory Attentional System

The need for a supervisory system arises when situations involve novelty, problem-solving, planning, decision-making, or overcoming a dominant habitual response that cannot alone be resolved through routine schema management (Shallice & Burgess, 1993). Since no schemas exist for an unfamiliar action, the Supervisory Attentional System (SAS) takes over and adjusts current strategies, creates a new schema, and implements it. Compared with well-practiced schema control, implementing a new schema under the SAS is slower, deliberate, and flexible. Managing both routine and novel schemas under the supervision of the SAS is what gives rise to coherent real world behaviour.

The Inhibitory Control Model

The main thrust of the IC model (Green, 1998) is that the control processes responsible for human action – routine schema management and implementation by the SAS – are also responsible for language selection in bilinguals. This means that whether one is withholding the desire to snack while on a diet, or avoiding speaking in English during a

Mandarin oral examination, the same underpinning control processes are engaged in each action sequence. How might the IC model capitalize on Norman and Shallice's (1986) model to account for bilingual language behaviour? Green achieves this by aligning control exerted by the SAS with a "language task schema" platform, that in turn exerts control on a bilingual's two languages (Figure 6). He also appeals to the RHM (Kroll & Stewart, 1994) to structure the bilingual lexicon within this control system.

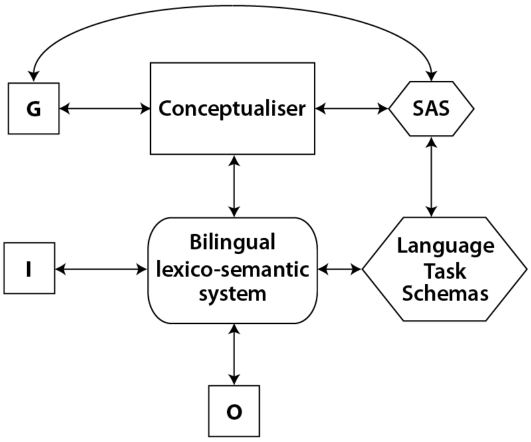


Figure 6: Green's Inhibitory Control model (adapted from Green, 1998). G = goal, I = input, O = output, SAS = Supervisory Attentional System.

Language schema management

In the IC model, the SAS serves to modulate the activity of language schemas. Upon having the intention to perform a language task, for instance, naming a picture in English (and not in Mandarin), the appropriate language schema is retrieved from the "conceptualizer". In the RHM (Kroll & Stewart, 1994), the conceptual store represents meanings without their word forms. Here, Green (1998) goes further to propose that the conceptualiser behaves similarly to long term memory where mental representations of world knowledge gained through experiences are stored in it. Thus, an intended language action draws from this conceptualizer and takes into account linguistic, affective, and pragmatic cues to finalize the assigned "goal" ("G") of English picture-naming. At the same time, this goal is constantly monitored by the SAS. Any novel changes in language tasks introduced by new "input" ("I") (switching into Mandarin, or naming a new picture) detected by the SAS will be modified accordingly. Once a language goal (picture-naming in Mandarin) has been set up and the appropriate language schema retrieved, the SAS implements the new schema on the "language task schema" platform, and it proceeds to interact with the "bilingual lexico-semantic system". Since the SAS is directly linked to the goal, it is able to transmit goal- and task-relevant information to the language task schemas. Via the same route, the language task schema has to continually adapt to the demands of the current goal and maintain appropriate activation levels within the lexico-semantic system to ensure that the "output" ("O") remains relevant.

Green (1998) states three ways in which schemas may alter, all of which involve the *suppression* of an irrelevant schema. First, unless the goal calls for repeatedly performing the same action, a schema suppresses itself once the goal is achieved. Second, an active schema can also be suppressed by another competing schema such as is the case in studies using the PWI task. Two competing schemas are activated, one by the picture and another by its distractor, but the irrelevant schema has to be suppressed to maintain the task goal. Third, if a change in goal is triggered by external cues, then a new schema will be retrieved, and the irrelevant one suppressed. For example, in a picture-naming task that cues for a response in L1, bilingual participants have to suppress a previously retrieved schema once the cue indicates for a change in language.

Two levels of suppression

A key characteristic of the suppression involved in the IC model is that it is *reactive*. Figure 6 shows that the SAS exerts this suppression on language at two levels. At the first level are language task schemas. Recall that in the RHM the L1 and L2 are linked via conceptual links. For unbalanced bilinguals, L1 is more strongly linked to concepts than L2, and in balanced bilinguals this is hypothesized to be equal. Accordingly, the IC model predicts that bilinguals with a dominant L1 will reactively suppress L1 more strongly than L2, when L1 is not in use during bilingual discourse. Fluent bilinguals on the other hand will exercise an equal amount of suppression under the same circumstances. This theoretical aspect of the IC model, that of applying differential amounts of suppression to each language, is examined more closely in Chapter 4 when the thesis moves into the topic of how bilinguals switch between their languages. For now, we focus on the other level of language suppression: the lexical level.

At the lexical level, the SAS exerts suppression via the conceptualizer and language task schemas to act on the bilingual lexico-semantic system to select the appropriate lemma. Costa et al. (1999) had suggested that the selection mechanism ignored lemmas in the irrelevant language. Green (1998) on the other hand proposes that lemmas from both languages compete for selection. A system of "language tags" (p. 71) provide information on a lemma's language membership and syntactic properties. Together with conceptual links in the RHM, these determine how strongly a lemma is activated. Thus, L1 and L2 lemmas may be activated to the extent that they share dominant conceptual properties, however, ultimately, accurate selection is achieved by applying reactive suppression on activated lemmas with inappropriate language tags.

Summary and Implications

Thus far, the review has highlighted a problem in bilingual language control – how do balanced bilinguals carry out language selection? Research on unbalanced bilinguals has been critical in shaping modern views on the bilingual lexicon but do not satisfactorily address the problem. With two active, competing languages systems, bilinguals need a mechanism to keep irrelevant competition from entering the selection process. Green (1998) offers an account of bilingual word production that implements a control over suppression at two levels, the language (schema) level and lexical level. Importantly, each act of suppression on a language or lemma is not a specialized linguistic process, but one that is similarly applied to other cognitive, non-language operations. If bilinguals are constantly exercising suppression over language units in addition to applying it in everyday cognitive tasks, then two implications follow from this. First, through the massive amount of practice they have had at suppressing language units, bilinguals should have honed this function to a high level. It follows then that when facing interference from another language unit, whether within the same language or from their other language, bilinguals should show an advantage over monolinguals. Second, since the suppression is executive in nature, bilinguals should similarly show an advantage over monolinguals in tasks of general, non-language suppression.

How do these predictions stand up to current evidence? With respect to language suppression, which in the present circumstance refers to the suppression of lemmas, we do not know of any study that has examined this ability across matched monolinguals and bilinguals. Related to this is the method of investigating lemma suppression through the monolingual version of the PWI task. This task is identical to the bilingual PWI task, except that stimuli, distractors, and responses are confined to one language. Distractors are manipulated in various word aspects to achieve a "related" and "unrelated" condition. The most well-reported finding in studies employing this task is that pictures are slower to be named in the related condition than unrelated condition (Lupker, 1979; Starreveld & La Heij, 1995), with the bulk of reported findings focused on the interference effects of semantically related distractors (e.g., Bajo, Peurta-Melguizo, & Macizo, 2003; La Heij, 1988). This phenomenon, known as *semantic interference effect*, is explained by the increased competition in activation that a related word presents to a target word (Glaser & Glaser, 1989). Figure 7 illustrates how a within-language distractor interferes in the naming process.

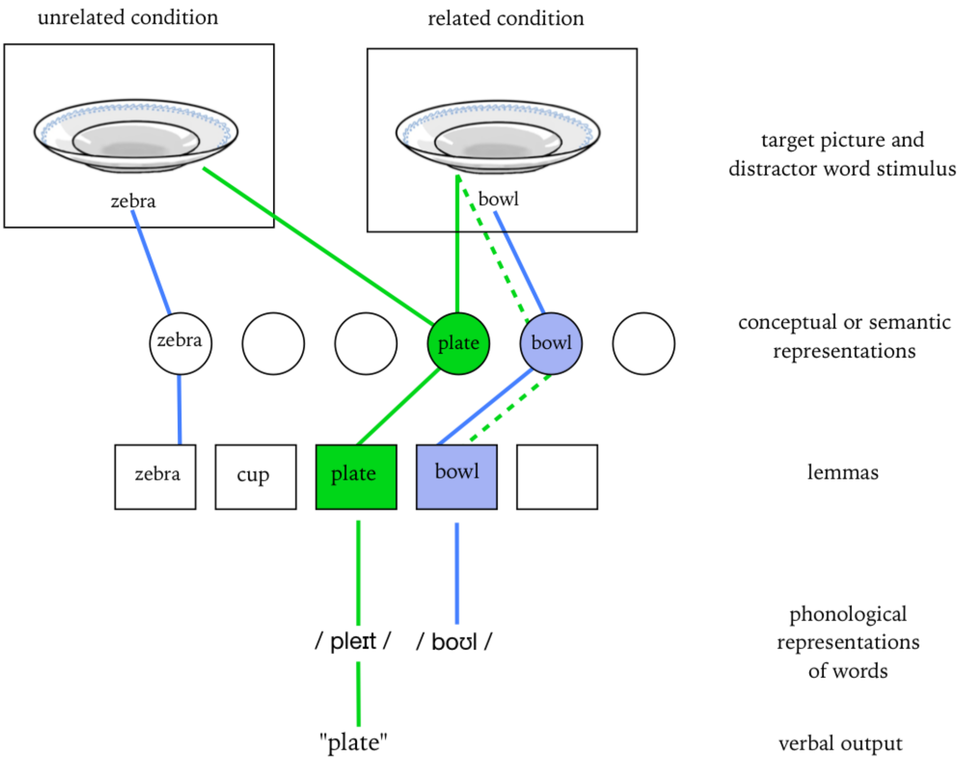


Figure 7: Stimuli from the picture-word interference (PWI) task comparing the unrelated condition (left picture 'zebra') and related condition (right picture 'bowl'). The lemma 'bowl' receives activation spreading from the picture (dotted lines) as well as direct activation from the word (bold lines). This makes it more highly activated than an unrelated lemma like 'zebra', which has only one source of activation.

When tasked to name the picture *plate* under a related condition with distractor *bowl*, *bowl* competes more actively than other lemmas as it has two sources of activation. An unrelated lemma like *zebra* has only one source of activation. A first source of activation for *bowl* comes via the orthographical route, when it is decoded and the lemma *bowl* is activated. A secondary source of activation comes from the initial activation of *plate*, that spreads to the lemma *bowl*, since it is a semantically related lemma. The activation of two lemmas to equal strength simulates bilingual selection conditions. However, in the studies employing this task, the language background of participants was not a variable and it remains unexplored as to whether bilinguals will show the hypothesized advantage over monolinguals at suppressing interference at the lexical level.

Research on bilingual and monolingual children provides a richer literature on which to examine the IC model. These investigations, carried out independently of the IC model, show that bilingual children perform better than monolingual children in language (Ianco-Worrall, 1972; Bialystok, 1986) and non-language tasks (Bialystok & Codd, 1997). However, without the support of a theory pinning down the source of the advantage then, these results were difficult to interpret. At present, the research appears to converge with the IC model, entertaining the possibility that executive processes mediate bilingual language selection. In the next chapter, we review the literature on the bilingual advantage in the language and non-language domains, and how developments in the area are attempting to extend their scope beyond studies on children.

CHAPTER 3 – THE BILINGUAL ADVANTAGE

Chapter Overview

This chapter reviews experiments that have examined the bilingual advantage in language and non-language tasks. Due to the lack of a theory explaining this advantage in early work, the research then appears to have taken a meandering path, without a clear focus on tasks or variables. Work by Bialystok (1986) narrowed the focus of the bilingual advantage to concepts of analysis and inhibitory control, and eventually, to that of the ability to suppress general interfering information. Following the proposal of the Inhibitory Control model (Green, 1998), Bialystok et al. (2004) noted that the mechanism responsible for suppressing general interference may be the same as that suppressing lexical interference. If this were true, then bilinguals, in managing an extra language, would have had twice as much experience as monolinguals in exercising suppressing interference. Based on this, bilinguals should show an advantage over monolinguals in standardized tasks of conflict. Bialystok (2006) and Bialystok and colleagues (2004, 2005, 2008a) then embarked on a series of investigations examining this claim, but, as we will find, this progress was not without its set of problems. The main problem is that the advantage in suppressing interference is not always replicated. This gap in the research forms the basis of Experiments 1 and 2.

Effects of Bilingualism

Early work

Before the 1960s, bilinguals were believed to be mentally inferior to monolinguals. The basis for this was the consistent demonstration of lower scores on psychometric measures of language and non-language tasks. Deficits were seen, amongst other language skills (see Diaz, 1983), in tasks of writing (Harris, 1948), and vocabulary (Barke & Perry-Williams, 1938, in Diaz, 1983). Based on a review of the relevant research then, it was concluded that the effect of bilingualism on cognitive development was largely negative (Macnamara, 1966). It is now known, as pointed out by Hakuta and Diaz (1985), that earlier experiments were methodologically flawed. For example, in an exploratory study of writing skills of Indian-English bilingual students, Harris (1948) makes no mention of a method to classify the bilinguals (or monolinguals) except for a self-indication of whether they spoke Indian, English, or Indian and English, at the time they enrolled into the school. In another study, Macnamara (1966) concluded that English-Irish bilingual children were inferior to their Irish monolingual peers in arithmetic based on arithmetic tests administered only in Irish. Since the bilinguals were tested in their weaker language, it was no surprise that they fared worse than monolinguals. Studies such as these contributed to the prevailing negative view of the effects of bilingualism.

Peal and Lambert's (1962) study marked a watershed in the perception of bilingualism. Aware of the lack of methodological rigour in earlier studies, they introduced the concept of "pseudobilinguals" vs. "true, balanced bilinguals". They aimed to capture as closely as possible the variables associated with cognitive development and bilingualism, and had these matched in 164 ten-year-old French-English monolingual and bilingual children. Factors controlled for included their school grades, parents' attitudes towards French and English, age, gender, and socioeconomic status. Children who could not be unambiguously classified as monolinguals or true bilinguals according to these variables were excluded from the study, a criterion that was lacking in previous studies. The participants underwent a series of tests that drew on spatial and perceptual functions, as well as the ability to manipulate symbols and concepts. The results showed that bilingual children performed significantly better than monolingual children on the majority of verbal and non-verbal tests administered, in particular, on measures of symbol manipulation and concept formation, that is, on non-language tasks. These results surprised the authors whose original intentions had been to locate the source of the bilingual deficit as suggested by the literature then, but who now found evidence suggesting a cognitive advantage in bilinguals.

Bilingual Effects in Language Tasks

In the wake of Peal and Lambert's (1962) study, more studies (Ben-Zeev, 1977; Cummins, 1978; Ianco-Worrall, 1972) supporting the positive effects of bilingualism followed. However, across studies results were often mixed, making it challenging to detect a regular pattern in the impact of bilingualism. In the review that follows, we consider only studies that used matched monolinguals and bilinguals, and that have contributed to the debate of whether bilinguals hold a cognitive edge over monolinguals.

Ianco-Worrall (1972) recognised that the bilingual advantage in symbol manipulation and concept formation reported by Peal and Lambert (1962) could indicate a flexibility in applying word meaning to word forms. As research in word memory at the time suggested, this ability is marked by children's and language learners' changing preference of acquiring words firstly through their acoustic or orthographic properties (word forms), and then later through their meaning (word meaning) (Bach & Underwood, 1970; Henning, 1970). In her paper, Ianco-Worrall referred to the case of Hildegard, a child who, despite the negative perception of bilingualism then, was raised bilingually in a "one-person-one-language" environment (Grammont, 1902, in Barren-Hauwaert, 2004). In his four volumes of work detailing Hildegard's speech development, Werner Leopold (1939 - 1949, in Hakuta, 1986) observed no detrimental effects on his daughter's speech and cognitive development, and on the contrary noted that she displayed a heightened sense of word awareness, often asking for a word in another language which had the same meaning as the one she had just learnt.

Based on research suggesting a form-to-meaning semantic development as children got older, and Leopold's (1939 - 1949, in Hakuta, 1986) assertion of Hildegard's agility with word understanding, Ianco-Worrall (1972) sought to obtain empirical evidence of Leopold's observations in terms of developmental semantic preferences. Would bilinguals, with proposed enhanced abilities of word understanding, display different semantic preferences compared with monolinguals? For her study, monolingual and bilingual children between the ages of 4 to 6 formed one group, and those between 7 to 9 years formed another group. They were matched on intelligence, age, sex, school grades, social class, and even their language environment – the bilinguals were raised with the one-parent-one-language approach. The children were exposed to eight three-word sets. Each word set consisted of one target word, and two word choices. Children were asked to pick a word choice that was closest to the target word in a question that was phrased, for example, as thus: "Which is more like *cap*, *can* or *hat*?".

The results of Ianco-Worrall's (1972) experiment confirmed the form-to-meaning preference. Older children preferred the semantic alternative (hat) than the phonetic alternative (can), while younger children displayed the reverse pattern. The most notable result was that young bilinguals far outnumbered young monolinguals in their preference for the semantic alternative. This indicated to the author that bilinguals attained a level of semantic development at least two to three years ahead of their monolingual peers, and that their accelerated semantic progress might be related to their awareness of the arbitrary relationship between words and their referents.

In a follow-up experiment on the same participants, Ianco-Worrall (1972) interviewed the children with three types of questions. The first asked for the meaning of words (e.g., "Why is a dog called a *dog*?"), the second asked if words and their forms could be interchanged (e.g., "Suppose we were making up names for things. Could you call a dog *cow* and a cow *dog*?"), and the third engaged them in word-interchanging play (e.g., "Let us call a dog *cow*. Does this *cow* have horns?"). Bilingual children excelled in the second type of question showing their increased consciousness of the arbitrary nature of words, but performed equivalently on the other two questions.

Ben-Zeev (1977) found the same result in her experiment which tested monolingual and bilingual children on their ability to separate word meanings from word forms, in two different tests. To use the examples she illustrated test items with in the first test, children would be asked while being shown a toy airplane, "You know that in English this is named 'airplane'. In this game its name is *turtle*... Can the turtle fly?... How does the turtle fly?". Children who answered correctly would have replied "yes" to the first question and "with its wings" to the second question. In the second test, the participants performed a more difficult task which required them to override the instinct to produce sensible, grammatical statements. An experimenter would ask, "For this game the way we say *I* is to say *macaroni*. So how do we say *I am warm*?". To respond correctly with *macaroni am warm*, children would have to make a word substitution and resist responding with the grammatically correct *macaroni is warm.* On both test items, bilinguals surpassed monolinguals.

Galambos and Hakuta (1988) carried out a longitudinal study that examined the performance of two cohorts of Spanish-speaking bilinguals, mostly from Puerto Rico, enrolled in a bilingual education program in the United States. The bilinguals had varying levels of English proficiency and were tested on Spanish-only tasks. The younger cohort was administered a syntax correction task and the older cohort an ambiguity judgement task. The syntax correction required students to judge sentences and correct a syntax error. Sentences were constructed to be of varying difficulty where easier sentences to judge were inconsistent with world knowledge (for instance, to use an English example, *ride the picture*) and the harder sentences had plausible meaning (e.g., *girl is swimming*). In the ambiguity task, sentences were used that contained polysemous items (e.g., *bark*), homophonous items (e.g., *pears* or *pairs*), or phonetically vague items (e.g., *engineer* or *engine ear*).

Younger bilinguals consistently scored better than younger monolinguals in the syntax correction task while the bilingual advantage surfaced in the ambiguity task in the older cohort at the second testing, that is, when the older cohort were tested a year later. This indicated to the authors that younger bilinguals, aside from understanding the meaning of a sentence, were also able to attend to the form of a sentence, while younger monolinguals tended to focus only on the message of a sentence. To explain why the bilingual advantage emerged only at the second testing of the older cohort, the authors put it down to the impact of an increased proficiency of English by the time the participants were tested again. This increase in English led to an overall “balancedness” of bilingualism which benefitted the older cohort in the ambiguity task.

An aspect of this study worth mentioning is the degree to which bilingualism was captured. Unlike studies which had sought to follow Peal and Lambert’s (1962) classification of bilinguals into a “pseudo” or “balanced” class (Ben-Zeev, 1977; Ianco-Worrall, 1972), Galambos and Hakuta (1988) noted that their sample of Spanish-English bilinguals was mainly Spanish-dominant. Even if they had scored well in the pre-experimental English assessment, the high scores in English were lower than the low scores in Spanish. Thus, their study grouped bilinguals into high- or low-Spanish proficiency, and high- or low-English proficiency. This formed four profiles, including previously unrecognised bilinguals who were weak in both languages, as well as those who were stronger in their second language than native language. Galambos and Hakuta found that the best performing bilinguals in the Spanish-only tasks were fluent in Spanish and English, as well as those who were strong in Spanish and less proficient in English, revealing an interesting compensatory relationship between the two languages for the latter group. Thus, aside from showing a complex pattern of bilingual effects, they also showed more convincingly that the degree, rather than the experience, of bilingualism played a role in native language performance.

However, studies did not always report a bilingual advantage. Cummins (1978) examined differences between monolingual and bilingual children on tasks that tested the ability to treat language objectively. Children were asked, for example, if the word *flimp,* representing a fairy tale animal, would continue to exist even if all *flimps* died, and if the same thing would happen to giraffes, would the word *giraffe* still exist. In another task, they were asked if the word *book* was made of paper, or if the word *bird* contained feathers. An advantage was found only in the former task, and not the latter. From this, Cummins concluded that the bilingual advantage did not extend to reasoning ability.

Rosenblum and Pinker (1983) found a null effect in their sample of Hebrew monolinguals, English monolinguals and Hebrew-English bilinguals who were tasked with substituting a nonsense word with a real word. However, they did find that in giving justifications to their responses as to why a word could be substituted or not, monolingual children tended to appeal to the physical properties of an object (e.g., “You can call a giraffe a *truck* because it has four legs and the hooves look like wheels.”) while bilingual children focused on the abstractness of naming (e.g., “You can call it a *cow* because it’s in our game.”). This indicated to the authors that subtle differences in the quality of word awareness existed between the groups.

Bruck and Genesee (1995) compared the phonological awareness of English monolingual and English-French bilingual children at kindergarten and Grade 1 levels. The first and second of three tasks required the children to count a word’s number of phonemes and its number of syllables. The third task tested the children's ability to interchange the onset of a word. Of the three tasks, kindergarten bilinguals showed an advantage in discriminating the onset of a word from its rime but this advantage was not evident in the Grade 1 group. The Grade 1 group showed a monolingual advantage in phoneme-counting, and a bilingual advantage in syllable-counting. The authors attributed the bilingual kindergarten children's advantage in phonological awareness to early bilingualism, and the later monolingual advantage to increased formal instruction in reading.

Up to this point, researchers noted that bilinguals excelled in areas of word knowledge that could stem from their experience of being bilingual. Importantly, these studies were methodologically sound, paying special attention to ensure that participants were matched. However, beyond well-controlled studies and an awareness of some kind of bilingual advantage, little could be concluded from the above reports.

Analysis vs. Control

Bialystok (1986) preliminarily organised what appeared to be forms of linguistic ability into two skill components. The first skill was the ability to *analyze linguistic knowledge*, and was responsible for explicating knowledge about language that had previously remained implicit or intuitive. Skills of analyzing linguistic knowledge played a central role in increasing functional knowledge of phonemes, words, and syllables, as well as understanding relationships between words and their meanings. The second skill, the *control of linguistic processing*, required that children were able to objectively look at aspects of language that were relevant to solving a problem, specifically, to be able to deliberately suspend meaning or form to achieve an outcome. For example, based on skills of analysis, a child might understand that a *dog* could be called a *cow* in a game. Upon being asked if the substituted *cow* had horns, it would require great effort to apply control to suppress the representation of a cow with horns, and focus attention on the abstract but relevant representation of *dog*. This would lead to the correct answer of "no, the 'cow' does not have horns". Therefore an important, intrinsic quality of control tasks that distinguished them from analytical tasks was that they incorporated misleading information that had to be overcome.

Based on the reports of a bilingual ability to separate word forms from their meanings and focus on a relevant aspect of language (Ben-Zeev, 1977; Ianco-Worrall, 1972), Bialystok (1986) hypothesized that bilinguals, if required in a linguistic task, would be better than monolinguals at ignoring distracting word forms, or word meanings, since they were more aware that words and their associated meanings were not cast in stone. That is, they would display a higher level of language control than monolinguals, but not necessarily higher level skills of language analysis.

To disentangle skills of language control from language analysis, Bialystok (1986) examined the ability of monolingual and bilingual children aged 5, 7 and 9 to judge grammatically correct sentences, irrespective of their meaning (e.g., Apples grow on noses.), as well as ungrammatical sentences, but which were meaningful (e.g., I have two pencil.). Depending on the instruction, they had to either focus on grammatical structure, or sentence meaning. This tested the children's ability to ignore a salient anomaly and focus on the sound aspect of language. For a counterbalanced design, the grammaticality and semanticity of sentences were manipulated to yield four types of sentences. The easier sentences to judge were either completely correct (grammatical and meaningful) or completely wrong (ungrammatical and not meaningful). The more difficult sentences were either ungrammatical, or not meaningful. A second task was administered where children had to make a syntactic correction in short sentences that were both ungrammatical and meaningless. A score was kept for each child for each accurate correction, and a separate score if they had managed to avoid correcting the semantically incongruent word. Bilinguals scored significantly higher than monolinguals on the tasks that required a focus on one aspect of language, as well as when they had to make a syntactic correction while resisting correcting the meaningless anomaly.

This display of the ability to resist responding to a salient cue also manifested in the non-language domain, hinting at a transfer of language skills across domains. Bialystok and Codd (1997) tested monolingual and bilingual children on a Sharing Task and a Towers Task. In the Sharing Task, children were shown two stuffed toy ducks and an even number of blocks. The set of blocks were evenly shared between the two ducks by having the children assist in giving the blocks, one at a time, to each toy animal in turn. After this, the children were asked to count the number of blocks one duck had. This task was administered two more times by replacing blocks with candies, then by toy animals. Monolinguals and bilinguals performed equivalently on the Sharing Task, demonstrating an acquisition of counting skill. In the Towers Task, children were shown a pair of towers consisting of the same type of block stacked upwards, with one made out of Lego blocks and the other made out of Duplo blocks, which were twice the size of Lego blocks on each dimension. The two towers could be described in either the number of blocks, or their height. After learning that each block represented a family that lived in it, the children were instructed to report which of two towers, the Lego or the Duplo, had more families living in it. The easy conditions were when the taller tower had more blocks, and the hard conditions were when the height of the towers did not provide clues to the number of blocks. This was when the Lego tower was shorter than or equal to the height as the Duplo tower, but contained more blocks than that tower.

The results of this task showed that monolinguals were better than bilinguals in the easy, non-conflicting conditions, while bilinguals were better than monolinguals in the conditions with conflict. Since both tasks tested the ability to count, which both groups had aptly demonstrated in the Sharing Task, what could account for the differential pattern of results in the Towers Task? Bialystok and Codd (1997) explained that the Towers Task differed from the Sharing Task in that to respond correctly in the conflicting conditions, children had to avoid attending to the perceptual height of the towers. Bilinguals appeared to have been better at this. As a result of basing their answers on counting the number of blocks rather than height, it could be that they had made more mistakes than monolinguals in the easy conditions. Bialystok and Codd attributed this advantage of focusing on task-relevant features to the bilingual need of having to constantly attend to one language from a dual-language system.

Bialystok and Majumder’s (1998) study provided further evidence for a bilingual advantage in control processes. They administered three non-language tasks to a group of children comprising English monolinguals, English-Bengali bilinguals with a weak second language, and English-French bilinguals with a strong second language. The first task was the Block Design task. This task presented the children with a set of nine identical cubes. Each cube had two surfaces of solid red, two surfaces of solid white, and two surfaces of half red and half white. Half red and half white surfaces had each colour separated by a square's diagonal. Children were shown a 3 × 3 red and white patterned grid on paper, and had to duplicate this pattern with the nine cubes within a time limit. During practice trials, the paper pattern to be duplicated appeared with a grid that demarcated nine equal cells forming a square, allowing some guidance to using the cubes to forming a 3 × 3 pattern. During the experiment, the paper pattern omitted the grid, increasing the cohesion of the 3 × 3 pattern. Efficient performance would require ignoring the summed pattern and concentrating on smaller square parts to systematically carry out a duplication. Since there was a source of distraction, that is, the summed pattern, bilinguals were anticipated to outperform monolinguals on this task. In the second task, The Water Level Task, children were shown a series of picture bottles presented in a booklet, with one bottle on each page. Each bottle was positioned in various orientations relative to the horizontal base of the table it was on. The children were asked to draw the water level of each bottle when they were half full. Again, since the bottle base presented a source of distraction to children, Bialystok and Majumder expected bilinguals to do better on this task than monolinguals. The third task, the Noelting Juice Task (Noelting, 1980, in Bialystok & Majumder, 1998), tested the analytical abilities of the children to evaluate numerical proportions. They were shown two displays, each set up in one booth. Each display had one empty jug, a few glasses of orange juice, and another few glasses of water. They were asked to indicate which jug would contain stronger orange juice if all of the drinks in the glasses in each display were poured into their respective jugs. Since there was no misleading stimulus, no group differences were expected in this task.

In short, the first two tasks tested the children's ability to ignore a distracting, irrelevant feature and shift focus to a relevant aspect of the task. These two tasks therefore tested for control processes. The third task could be properly approached by counting and carefully evaluating relative numerical amounts, and therefore mainly tested analytical skills. True enough, the authors found a bilingual advantage in the Block Design and Water Level tasks, although this advantage was confined to bilinguals who spoke two languages fluently. The equivalent results of all groups on the Noelting Juice Task reaffirmed Bialystok's (1986) proposal of a control vs. analysis divide on cognitive tasks, as well as that being proficient in a second language contributed to benefits in cognitive control.

Following her and others' findings in both the non-language and language domain, Bialystok (2001) followed up on her previous hypotheses (Bialystok, 1986) and formally posited two forms of cognitive processing underlying language task performance. The first she called the *analysis of representational structures* and the second was the *control of attention*.

Elaborating on this process, Bialystok (2001) referred to the analysis of representations as the ability to "construct mental representations with more detail and structure than was part of their initially implicit knowledge" (p. 177). This type of process added greater depth to acquired pieces of representations of knowledge and the ability to understand increasingly complex relationships between these representations. Bialystok, Martin and Viswanathan (2005) used the example of children's memorization of the alphabet to illustrate this process. In the beginning, as children develop and apply analysis to the alphabet, they come to understand that the alphabet is composed of letters, and that each letter represents a sound. Letters can combine into strings under particular rules, and these strings acquire meanings of learned concepts. As children's skills of analyses deepen, they begin to detect larger patterns and are able to organize knowledge around categories and can access representations independent of a context. What began as a memory routine learnt from a particular context, becomes a tool to navigate representations.

The control of attention referred to the ability to direct "attention to specific aspects of either a stimulus field or a mental representation as problems are solved in real time" (p. 178). Specifically, the need for control arose when conflict or ambiguity was part of the present context. By this, Bialystok (2001) emphasized that control processes were involved when one response had to be selected from two plausible representations. Accurate response selection was dependent on the success of attending to the appropriate representation and suppressing the misleading one. She stated:

> Simply put, tasks that are high in their demands for control of attention are solved better by bilinguals than monolinguals; tasks that are high in their demands for analysis of representations are not necessarily solved better by either group. The bilingual advantage, therefore, is in the ability to control attention when there is misleading information (p. 179).

Furthermore, because the control of attention was much more difficult if a representation was particularly misleading in that it contradicted the target representation, successful response selection was largely dependent on the control of inhibition imposed on the misleading representation. Therefore, more so than attentional control, *inhibitory control* was responsible for the bilingual advantage (Bialystok et al., 2005).

This inhibitory control hypothesis explained why bilinguals were better able than monolinguals in responding to the question if *turtles* could fly in the word-substitution game that had interchanged *airplane* with *turtles* (Ben-Zeev, 1977). According to Bialystok (2001), bilingual children found it easier than monolingual children to suppress the representation of a non-flying turtle triggered by the experimenter's question, and directed attention to the relevant representation of an airplane. Bilingual children also managed to substitute *macaroni* for *I* in the sentence *I am warm* to produce the idiosyncratic *macaroni am warm* statement (Ben-Zeev, 1977). To do this successfully, children had to suppress the grammatically correct and meaningful representation of *macaroni is warm* and shift attention to substituting the word *I*. This was also the case in Ianco-Worrall's (1972) word-substitution task, and Galambos and Hakuta's (1988) study in which bilinguals were better able than monolinguals to ignore distracting sentential anomalies to focus on a specified aspect of language. The view also found support in Cummins' (1978) data, who reported that bilinguals performed better than monolinguals on a word substitution task, but not when they were tested on evaluating a word's property. Perhaps the application of inhibitory control by bilinguals was most clearly demonstrated in non-language tasks where children had to suppress a strong perceptual cue and divert their attention to a task-relevant feature for an efficient or accurate response

(Bialystok & Codd, 1997; Bialystok & Majumder, 1998). Although there was data that could yet be accounted for (Bruck & Genesee, 1995; Rosenblum & Pinker, 1983), no other model was able to explain the consistent advantage seen across tasks in a substantial number of studies as well as the inhibitory control hypothesis.

Measuring inhibitory control

From these investigations on the positive effects of bilingualism, it appeared that bilinguals did enjoy a sort of enhanced inhibitory control in language and non-language tasks. There was however a problem with the bilingual advantage demonstrated in the type of control tasks administered so far. The problem lay in assuming that there was an active, competing representation in each of these tasks so much so that without suppressing this interfering representation, performance would be led astray. This assumption might not necessarily be true. For example, in instructing children to substitute *I* with *macaroni* in the sentence *I am warm,* it was assumed that children would naturally call up the construction *macaroni is warm* to compete with the correct response *macaroni am warm*. This might not have been the case as it was possible that bilinguals focused solely on the task, without giving too much thought to its correct alternative even though they might have been aware that their response did not sound right. In other words, correct responses could have been an indication that children found it easier to mechanically switch words than an ability to suppress a conflicting representation.

This problem extended to non-language tasks. In the Towers Task (Bialystok & Codd, 1997), it was assumed that the perceptual height of each Lego and Duplo tower was first processed, and therefore imposed a dominant representation that children had to suppress if they were to solve the task by block-counting. In Bialystok and Majumder's (1998) study, it was also assumed that the summed pattern produced in a 3 × 3 matrix without a grid triggered a distracting representation and hindered assembling the pattern by parts. This assumption was extended to the salience of a container's form in the Water Level Task that would draw away from the table's horizontal surface and mislead some participants to wrongly indicate the water level in the container. In each of these cases, the degree of salience of misleading information was not controlled for, and confounded the measure of task ability. It was possible that bilinguals, in being instructed to focus on a particular aspect of a task, did not find the irrelevant task aspects distracting in that irrelevant features were simply not activated to the levels that they could disrupt focus. If the relevant aspects of a task were naturally primed based on prior task instruction, then response selection could have proceeded from the highest activated representation without involving inhibitory control.

Therefore, one way to interpret the bilingual advantage in the ability to ignore misleading cues was that bilinguals simply did not activate competing representations as strongly as monolinguals, even though both language groups were equal in inhibitory control ability. A solution to this was to measure inhibitory control, in which case a task was needed that enabled the collecting of empirical evidence that such inhibition actually took place. As Dagenbach et al. (2007) wrote in their work on inhibition,

> …we look for confirmatory evidence consisting of an inhibitory signature left by the selection process: Access to the competing information is shown to be impaired from the act of selection. If this signature is present, then we conclude in favor of inhibition. If this signature is absent, then other ways of resolving interference must be invoked to explain the results (p. 46).

In other words, a more convincing demonstration of the bilingual advantage in inhibitory control would be to isolate its impact on accurate response selection. Related to this problem was the obvious unsuitability of the above-discussed tasks for populations other than children. Therefore, the challenge here was to find a task that clearly invoked competition among representations, that would suitably measure inhibitory control across ages and language groups.

At this point in the thesis, it may be apparent that Bialystok's (2001) attempt to provide an attentional-control framework to understand the bilingual advantage converged nicely with Green's (1998) theory that inhibitory control was responsible for bilingual language production. In his model, Green proposed that the irrelevant language was reactively suppressed by the same inhibitory mechanism that suppressed non-language behaviour. The implication of this model was that with constant practice through daily communication, bilinguals had far more experience at applying inhibitory control than monolinguals. If

Bialystok's observations that bilingual children were better at inhibitory control than monolingual children was valid, and if Green was correct about the executive nature of language inhibition, then the broad claim was that an empirical demonstration of a bilingual advantage in non-language inhibitory control would lend support to the hypothesis that bilingual language control was mediated by executive control.

Bilingual Advantage in Inhibitory Control

The Simon task

One way to address the task problem outlined above is to use tasks designed specifically to tap into inhibition. These tasks typically draw on the ability to ignore distracting stimuli, or override a particular state of mind. Three types of inhibition tasks have been used to examine the bilingual advantage in inhibitory control. These are the Simon task, the flanker task, and the antisaccade task. The stimuli type in each task varies (colour patches, arrows, and so forth) and each stimulus feature is associated with a left or right keypress response except for the antisaccade task which uses for its responses a left or right eye gaze. This section follows the work of Bialystok (2006) and Bialystok and colleagues (2004, 2005, 2008a) who have mainly used the Simon task. Research using the flanker task (Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Emmorey et al., 2008) is reviewed in the latter part of this section.

In the simplest version of the Simon task, a trial begins with a centralised fixation, and is replaced by a stimulus appearing to the left or right side of it. A non-spatial attribute of the stimulus such as its colour or shape indicates to the participant if a left or right keypress response is required, irrespective of its location. The two response keys located on a standard keyboard may be marked with corresponding colour or shape patches to assist children with associating a colour to its assigned spatial attribute, or are otherwise marked with arbitrary symbols. In this task, location information is irrelevant but the finding is that participants are slower to react when the stimulus attribute is in conflict with its location than when it is not (Lu & Proctor, 1995). For example, participants are slower to react to a blue square to which they have been instructed to respond with a left keypress, when it appears on the right side of a screen.

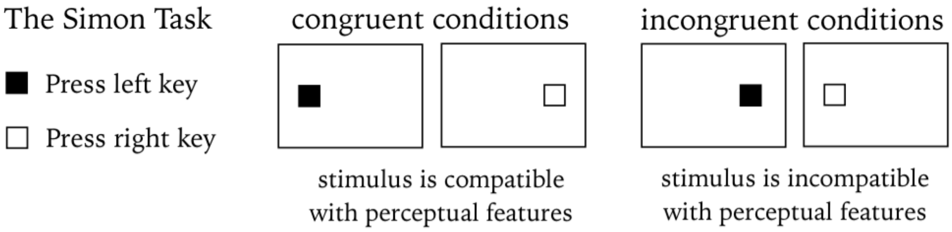


Figure 8: The basic Simon task showing congruent conditions (left two screens) and incongruent conditions (right two screens). Participants are slower to react in incongruent conditions than in congruent conditions.

The delay in reaction time has been attributed to the involuntary processing of the irrelevant dimension (Lu & Proctor, 1995) because it is a source of interference for participants. This provides researchers with an empirical method of isolating the effects of inhibitory control from uninterrupted response selection: The additional time taken to react to the stimulus when it is in conflict with its location than when it is not represents the degree to which participants have to suppress interference.

Variants of the Simon task have been used, but the principle of subtracting a condition that differs from another by a single feature to calculate the degree of interference remains the same. This result is referred to as the *interference effect*. The task can be manipulated to be simple enough to use with young populations, and yet is not so trivially easy that adults can do it effortlessly. For example, by increasing the number of features to attend to, or by running trial sequences quicker, the task can be made more challenging. Thus, through the interference effect, tasks such as the Simon task provide an index of inhibitory control and satisfy the criteria on which to examine the bilingual advantage.

Behavioural studies

In their work on bilinguals using the Simon task, Bialystok (2006) and Bialystok and colleagues (2004, 2005, 2008a) arrived at this general conclusion: bilinguals were superior to monolinguals in tasks of executive control because of their language experience. However, a closer examination of the data in this set of research revealed a less than straightforward pattern that weakened their position. We discuss this set of investigations in this section.

In their first paper reporting a bilingual advantage in inhibitory control, Bialystok et al. (2004) carried out a series of experiments using different versions of the Simon task. The first experiment used the standard Simon task as depicted in Figure 8. Equal groups of monolinguals and bilinguals comprising middle-aged adults (mean age = 43) and older adults (mean age = 71.9) were instructed to press a left shift key marked “X” when they saw a blue square and a right shift key marked “O” when they saw a red square. All participants completed 28 trials. The results showed that overall, bilinguals were faster than monolinguals in performing congruent trials, and that middle-aged bilinguals were notably faster than older bilinguals. The critical difference favouring bilinguals over monolinguals in the contrast of incongruent vs. congruent trials was also demonstrated, providing support for the bilingual advantage.

In the second experiment, the task was substantially more difficult and the number of trials was increased to 192. There were four conditions in total, two conditions where the stimulus appeared only on the screen side, and two control conditions where the square stimulus appeared only in the screen centre. The first condition was the standard Simon task. In the second condition, a total of four colours were used; two colours were assigned a left response and two other colours were assigned a right response. The third and fourth conditions were controls for the first two conditions; stimuli appeared only in the centre of the screen. Results showed that the bilingual speed advantage on congruent trials was replicated, supporting the results in the first experiment, and that the addition of two more colours was significantly harder for monolinguals than bilinguals. Importantly, this confirmed Bialystok’s (2001) observation that a bilingual advantage in inhibitory control was more pronounced under more demanding conditions. In terms of interference effects, older monolinguals showed a greater increase in reaction time compared with their middle-aged counterparts, than did older bilinguals with their middle-aged cohort.

At a glance, these results seemed to be anticipated. There was however an aspect of their data that raised questions about the interpretation of their results. This was that in both experiments, bilinguals were also significantly faster than monolinguals on congruent trials. Since congruent trials were conflict-free and required no inhibition, the IC model did not predict such an outcome. The relevance of demonstrating a bilingual advantage in the interference effect across age groups was not only to link the phenomena which was studied in children with language and non-language tasks suited for their age group only, but also to validate that the experience of suppressing the irrelevant language boosted the specific ability of suppressing interference. The idea that bilinguals might show an advantage in areas other than interference suppression suggested that the benefits of bilingualism might be more far-reaching than was hypothesized, and raised the possibility that the source of the bilingual advantage might be the consequence of an experience other than suppressing an additional language. This alternative was also raised by other researchers noting the discrepancy in Bialystok et al's (2004) result (Hilchey and Klein, 2011).

Another study further explored the bilingual advantage in young undergraduate adults and older adults. Bialystok et al. (2008a) administered a variant of the Simon task in three conditions. In the first control condition, an arrow appeared in the centre of the screen and the instruction was to respond as quickly as possible to the direction of the arrow. In the second condition, the arrow appeared to the left or right of the centre, testing for the standard interference effect. The third condition was a unique trial where the arrow appeared in the centre, but the instruction was to indicate the opposite direction of the arrow. Therefore, in this condition, participants had to suppress the reflex of responding in the arrow's direction. Although inhibitory control was needed, this condition differed from the second in that there was no perceptual conflict to overcome.

The results of this experiment showed no group differences in the first and third condition, which were the equivalents of the control and "reverse" conditions. Basically, if the arrow appeared in the middle of the screen, all participants performed equivalently. In the second condition where the arrow appeared on the sides, older monolinguals showed a greater interference effect than older bilinguals, but this was not evident in younger monolinguals vs. bilinguals. Also, the unanticipated advantage that bilinguals previously showed on congruent trials was not evident. This experiment therefore did not replicate the bilingual advantage in young adults and, for the older group, raised an interesting question: Why did older bilinguals only outperform older monolinguals in the interference suppression condition and not the reverse condition?

As mentioned before, the third condition differed from the second in that there was no perceptual conflict, but participants had to resist responding according to the arrow direction. According to Bunge et al. (2002), this was a test of *response inhibition*, a type of inhibitory control that required overriding a habitual response that was more often associated with motor control, and was distinct from *interference suppression*, the form of inhibitory control elicited by the Simon task. Bialystok et al. (2008a) explained that older bilinguals excelled at interference suppression and not response inhibition because the experience of having a second language honed the skill of suppressing the unneeded language. Response inhibition was needed in situations of refrain, and was characterised by the stopping of an ongoing response (Aron, Robbins, & Poldrack, 2004), as will be elaborated on later. The dissociation of the effect of bilingualism between interference suppression and response inhibition found support in one other study (Martin-Rhee & Bialystok, 2008), an investigation we return to towards the end of the next section. Thus, the interest of this finding was that the bilingual advantage was not simply in inhibitory control, but more specifically in the inhibitory control of interference suppression.

Interference Suppression and Response Inhibition

The suggestion that bilinguals ought to show an advantage over monolinguals in skills of interference suppression was consistent with a basic model of bilingual language production. This view advanced that lemmas from two languages were in constant competition and the semantic interference effect was evidence of the interference lemmas posed during bilingual discourse (Hermans et al., 1998; van Heuvan et al., 2008). To counter this, executive inhibitory control was invoked to suppress the interfering lemmas (Green, 1998). The notion that the inhibitory control mechanism covered non-language operations was supported by studies on bilingual children showing a superiority in ignoring linguistic anomalies that seemed to parallel suppressing distracting, irrelevant aspects of non-language tasks (Bialystok & Codd, 1997; Bialystok & Majumder, 1998). Now, it appeared that this ability to suppress interference was a type of inhibition, and could be contrasted with other types of inhibition, in particular, response inhibition, in which bilinguals had no reason to show an advantage.

Why would bilinguals not show an advantage on tasks of response inhibition? In contrast to interference suppression, response inhibition was associated more closely to motoric processes (Aron et al., 2004) and did not involve resolving conflict between competing response options. Friedman and Miyake (2004) defined response inhibition as “the ability to suppress dominant, automatic or prepotent responses” (p. 104). Therefore, the primary process involved in response inhibition was the overt withholding of an intended response execution, rather than the ability to turn one’s focus away from conflicting stimuli to choose another response option. This process is conventionally examined through a *go/no-go* paradigm. In the traditional set up of this paradigm, participants are exposed to a series of stimuli that cues one of two possible responses. If a stimulus conveys a *go* signal (e.g., a green circle), participants execute a prepared response as quickly as they can. If however the stimulus conveys a *no-go* signal, then participants must withhold their prepared response. It is imperative that stimuli on no-go trials are processed *after* participants formulate an action plan so as to elicit response inhibitory processes. For this reason, the number of no-go trials are often substantially outnumbered by go trials to induce in participants a state of ongoing response (e.g., Braver, Barch, Gray, Molfese, & Snyder, 2001). Response inhibition ability then is represented by the percentage of correctly withheld responses on no-go trials.

Bunge et al. (2002) provided evidence of the distinction of these two processes using a modified flanker task in a neuroimaging study. The basic flanker task consists of a centralised left- or right-pointing target arrow that is flanked by two distractor arrows on each side of the target. This produces a line of five arrows, but participants are instructed to respond only to the middle target arrow. Information supplied by distractor arrows is irrelevant, but when their direction is in conflict with the target arrow (→ → ← → →), response times are slower than when the target is congruent with the distractors (→ → → → →) (Costa et al., 2009). Similar to the Simon task, the slower response times are attributed to the interference caused by incongruent distractors compared with when distractors are congruent with the target. Bunge et al. used the basic congruent and incongruent flanker conditions to test for interference suppression, and added two more conditions, go and no-go, to test for response inhibition. In the go condition, the target was flanked by outlined diamonds (<> <> → <> <>), to which a left or right response was to be executed, and in the no-go condition, it was flanked by a series of crosses (× × → × ×). In the no-go condition, no responses were to be made. Altogether, there were four conditions: congruent, incongruent, go, and no-go.

The manipulation of distractors in the go/no-go conditions compared with the congruent-incongruent conditions is believed to be the critical factor in determining which sort of inhibitory process is elicited during performance. In the congruent-incongruent condition, participants have to suppress stimuli that interfere with accurate processing of the central target. However, no such competition is present in the go/no-go conditions and therefore no involuntary processing or irrelevant stimuli is possible. In other words, under interference suppression conditions, participants must overcome the perceptual conflict created by the distractors and the target while under response inhibition conditions, attention is focused on decoding the distractors that inform participants whether or not to execute a prepotent motor response. Furthermore, all four conditions in the experiment occurred equally frequently. For Bunge et al. (2002), this put the probability of having to withhold a response at 25%, encouraging participants to be response-ready if performance was to be optimized.

Bunge et al. (2002) tested young adults and children in this task. They observed that during response inhibition, children used a subset of the brain areas that were recruited by adults, while the interference suppression task activated different areas in both groups. These results raised the possibility that prior to brain maturation, children acquired response inhibition skills. The arguably higher-order task of inhibiting distractions occurred later in life. Compared with a motoric form of inhibition, it appeared that the executive ability to ignore irrelevant distractors and in the process resolve conflict was one that required practice over time, which young adults in the experiment showed. Bialystok et al. (2008a) later pointed out that it was precisely this skill that speakers of more than one language seemed to be adept at compared with monolinguals.

At least two behavioural studies (Emmorey et al., 2008; Martin-Rhee & Bialystok, 2008) have investigated interference suppression and response inhibition processes in monolinguals and bilinguals. These studies claim to be consistent with the bilingual advantage. However in each case, we find that the advantage refers to the performance of congruent trials, or incongruent trials, rather than the index of interference suppression which is the contrast between incongruent and congruent trials.

In the first study, Emmorey et al. (2008) used a similar version of the above flanker task to examine three middle-aged groups. These were monolinguals, regular bilinguals, and signing bilinguals. Signing bilinguals are individuals who can communicate through speaking and sign language, and can therefore be considered to be managing two languages although they are not limited to one form of output at a time. All flanker task conditions were the same as that used by Bunge et al. (2002) except that a control condition where a single arrow appeared in the middle of the screen was added, and that the target arrow appeared to the left (← → ← ← ←) or right (← ← ← → ←) off the centre in the interference suppression conditions. Of five conditions, control, congruent, incongruent, go, and no-go, regular bilinguals were significantly quicker in performing go trials than the other two groups who showed no differences. This was also the case for the congruent and incongruent trials. Crucially, the lack of an interaction between groups and congruency showed that in terms of interference effects, regular bilinguals were not different from signing bilinguals or monolinguals.

In the context of previous studies, Emmorey et al. (2008) replicated Bialystok et al's (2004) result of an observed speed advantage shown by bilinguals on congruent trials. If the circumstance of using two languages was responsible for enhanced interference suppression, how is it that signing bilinguals were slower than regular bilinguals? Emmorey et al. (2008) speculate that the constraint of a single mode of output necessitated, more than the suppression of unwanted words, other aspects of executive control. These included processes such as attention, monitoring, and task switching. Even though the signing bilinguals were similarly constrained when communicating with other nonsigning English speakers, they signed and spoke simultaneously within their signing community which did not require the continual mediation of two languages for a single mode of output. For instance, they were able to speak and sign the same word that shared a conceptual representation. This would have resulted in a reduced degree of executive control ability when compared with regular bilinguals. Therefore, the novel result was that being bilingual did not necessarily enhance executive control – it was the need to suppress one language in order to let the other proceed that determined the enhancement (a practice which was available to most regular bilinguals).

Martin-Rhee and Bialystok (2008) reported similar effects in their study on children. They administered the standard Simon task with blue and red colour patches and found that bilingual children were faster than monolingual children in congruent and incongruent trials. They however did not find significant differences between the two groups when interference effects were assessed. Following this experiment, Martin-Rhee and Bialystok used the same variant of the Simon task employed by Bialystok et al. (2008a) to test for interference suppression and response inhibition on a new group of monolingual and bilingual children. The children were tested in three blocked conditions. In the first condition, an arrow was presented in the middle of the screen and children had to press a key to indicate its direction; this condition corresponded to a go trial in the go/no-go paradigm. In the second reversal, or no-go, condition, they were told to press the key in the opposite direction. Children therefore had to cancel the natural tendency to respond in the direction of the arrow to successfully perform the reversal condition. In the interference suppression condition, the arrow could appear on the left or right side of the screen, and thus its position and screen location could either be in agreement (left arrow on the left side) or in conflict (left arrow on the right side) with the screen side.

There were two notable results. Monolingual and bilingual children performed equivalently in the conditions where the arrow appeared in the middle of the screen, which would be the Simon equivalent of go/no-go trials. This was different from Emmorey et al. (2008) who found that bilinguals were faster than monolinguals in go trials, but consistent with the results of Bialystok et al. (2008a) who found no group differences between older and younger bilinguals under go/no-go conditions. The next result was that bilinguals were faster than monolinguals in congruent and incongruent trials, but when these two conditions were contrasted to assess for the interference effect, the difference was not significant between the two groups.

At this juncture, it appears that in examining the bilingual advantage, more questions have turned up than answers have been provided. Mixed results of a bilingual advantage seen in young adults and children, but a consistent pattern seen in older adults, plus reports of a different advantage in tasks other than that requiring conflict control, raise the question of whether or not practice in suppressing a competing language boosts inhibitory control. Therefore the question remains, do bilinguals have an advantage in interference suppression as measured by a reaction-timed conflict task? In clarifying this, we may gain a theoretical understanding of the bilingual advantage since interference suppression ability is tied to inhibitory control theory.

Summary

This chapter examined the effects of managing an additional language on language and non-language tasks. If a bilingual advantage over monolinguals could be aptly demonstrated in these tasks, this would suggest a transfer of language skill over to the non-language domain and validate the theory that bilingual lexical selection is carried out through executive inhibitory control. Bilingual children appear to show an advantage in language and non-language tasks, but more refined methods reveal that this advantage, operationalized as the time taken to overcome a source of perceptual conflict compared with a control condition, show mixed results.

Bialystok et al. (2004) demonstrated the bilingual advantage in younger and older bilinguals, but in a different experiment (Bialystok et al., 2008a), only the older group showed the advantage. In subsequent studies juxtaposing interference suppression with response inhibition (Emmorey et al., 2008; Martin-Rhee & Bialystok, 2008), a different sort of bilingual advantage seemed to emerge, with these studies finding an overall bilingual speed advantage in congruent trials and incongruent trials. The speed advantage on congruent trials is not consistent with the predictions of the IC model which espouses that the key to bilingual language control is in suppressing lexical interference. With respect to the speed advantage on incongruent trials, while these trials present conflict, unless they have been controlled against congruent trials, they do not reveal definitively how participants react to interference in relation to where there is none. For example, if monolinguals were slower than bilinguals to begin with, then this needs to be taken into account when analysing their reaction time on incongruent trials.

To conclude, the inconsistent results of bilinguals showing an advantage in interference suppression limits the generality of the bilingual advantage based on the IC model. This issue forms the basis of Experiments 1 and 2 in the thesis. In this set of experiments, we tested young adult Singaporean monolinguals and bilinguals in their ability to suppress non-language interference and language interference to see if a bilingual advantage could be demonstrated in the language and non-language domains.

CHAPTER 4 – LANGUAGE SWITCHING

Overview

After an examination of the bilingual advantage in Chapter 3, we now look at the application of the Inhibitory Control (IC) model in language switching research in Chapter 4 since this allows us to examine bilingual language control from a different angle. While interference paradigms require bilinguals to ignore an unused language, language switching experiments induced them to use both languages. In these experiments, bilinguals are shown a series of stimuli to which they must respond in either of their languages. Each stimulus is accompanied by a cue that indicates the language of response. The studies examining the IC model in relation to language switching have yielded important insights into language control. However, beyond this circumscribed set of studies, little else has been explored.

This chapter serves as the background to Experiments 3A, 3B, and 4, which examine language switching more deeply than previously done. Experiments 3A and 3B for example examine the processes that occur after the experimental cue in the language switch paradigm; Experiment 4 examines those that occur before the experimental cue. The current chapter makes clear why this is important to do. The current chapter also discusses a methodological issue that has previously been identified in non-language task switching research but that has not yet been taken into account in language switch experiments. Experiments 3A, 3B, and 4 address this.

As such, the literature review in this chapter does not intend to match previous studies' emphases of validating the IC model through predicted language switching patterns, but rather, it also explores possible similarities in pre- and post-cue processes between language and task switching behaviour, and revisits the language switching methodology. In doing this, the chapter continues to fall on the IC model to explain language switch research, and also draws on two task switch theories, namely, *task set inertia* and *task set reconfiguration*.

The first half of the chapter opens with the discussion of an early study that is representative of language research carried out at the time. It then sketches the development of this field leading to present-day research that centres on the predicted behaviour of a critical dependable variable, the *language switch cost*. According to work in the task switch domain and the IC model, the language switch cost varies as a function of language proficiency. Before reviewing the research with respect to this variable, we outline the basic experimental paradigm that is used to examine how participants switch from one action to another. In the latter half of the chapter, significant developments in task switch research with which language switch research has not kept pace are introduced. The first of these developments relates to examining the language switch cost as a function of time, and is directly motivated by the theories of task set inertia and task set reconfiguration. These theories, and their implication in language switch research, are discussed. The second of these developments questions the reliability of the basic switching paradigm. The effects of cue-processing are addressed and the chapter concludes with future directions for language switch research.

Early Work

Penfield and Roberts (1959, in Rojczyk, 2011) were the first researchers who tried to explain how bilinguals controlled the use of their languages. They postulated a "curiously effective automatic switch that allowed each individual to turn from one language to another" (Penfield & Roberts, 1959, cited in Rojczyk, 2011, p. 212). At the time, attempts to characterise this language switch were relatively basic (e.g., Kolers 1966; Macnamara & Kushnir, 1971) compared with current research methods (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999). For example, in one of these experiments, Macnamara and Kushnir (1971) tested French-English bilinguals on their ability to silently read four separate similar-meaning paragraphs by marking out their progress with a pointer. The linguistic content of each paragraph was manipulated such that unilingual paragraphs were only in French or in English, and bilingual paragraphs followed either a French-only or English-only word order, but were mixed with approximately equal numbers of syllables in each language. The time taken to read each paragraph was measured with a stopwatch, and switching time was calculated by averaging the difference between the time taken to read unilingual paragraphs and that of their matched bilingual paragraphs.

Despite the primitive means of investigating language switching, these studies highlighted an important, consistent observation: processing mixed-language material resulted in a time cost compared with processing material that was only in one language (Kolers, 1966; Macnamara & Kushnir, 1971). Macnamara (1967) believed that the time cost was due to the dominance of a language that made it harder to suppress and was consequently easier to produce, while a weaker language would be easier to suppress, and thus harder to respond in. He came to this conclusion in his language switching study which tested four groups of bilinguals. The bilinguals ranged from having a very high to very low proficiency in a second language. Two single-language conditions and two language switching conditions were administered. In the single language conditions, bilinguals were given three minutes to name as many words as they could in L1. This was then carried out in L2. In the language switching conditions, they were given one minute to say as many different words as they could, and every second word had to be in a different language (L1, then L2, then L1 again). The other language switching condition required every second word to be the L2 translation of the L1 word that preceded it.

Macnamara (1967) found in the single language conditions that as L2 proficiency decreased, fewer words were generated in L2 than in L1. This indicated to him that unbalanced bilinguals were less able to produce L2 words despite being able to recall their meanings. However, in the language switching conditions, no differences in the number of items produced were seen between groups. How is it that unbalanced bilinguals, having showed that they were inferior in producing L2 words, appeared to switch as proficiently as balanced bilinguals? Macnamara explained that “the ease in making a correct response is exactly balanced by the difficulty in inhibiting a wrong [language].” (p. 734), therefore, under language switching conditions, unbalanced bilinguals accessed L2 words by strongly inhibiting the wrong L1 word, and accessed L1 words while applying a weak inhibition on the wrong L2 word. This allowed them to counter the performance of balanced bilinguals who would exercise the same amount of inhibition on each language. The number of items generated by each bilingual group under single- or switching-language conditions gave Macnamara an idea that balanced and unbalanced bilinguals may be handling their languages via suppression, however, the lack of data on the time taken to generate a single word in the L1 or L2, as well as the direction of the language change (switching from L1 to L2, and vice versa) made it difficult to verify his theory.

Little attention was paid to the field thereafter until three important pieces of work revived interest in language switching research. First, Allport et al. (1994) showed that when participants switched between two cognitive tasks of different difficulty, they took longer to switch into the easier task than they did to switch into the more difficult task. Second, Meuter and Allport (1999) confirmed that bilinguals showed the same pattern when they switched between two languages of different proficiencies. They took longer to switch into the weak language than they did to switch to the strong language. From this, Meuter and Allport concluded that the same mechanism was responsible for the control of language and non-language tasks. Thus, these two studies were seminal in providing the link between language and non-language control. As each of them was carried out in different contexts (the first being a contribution to task switch theory and the second being an influential report in modern language switch research), we defer their discussion until later in the review. The third piece of work that has stimulated much of current language switch research is Green's (1998) IC model. The IC model maintains the views of Meuter and Allport, but goes a step further to integrate this work with Norman and Shallice's (1986) influential theory of executive control and Kroll and Stewart's (1994) model of the bilingual lexicon.

Inhibitory Control of Language Schemas

The IC model was described in detail in Chapter 2. An outline of the model is provided here for ease of reference. It was highlighted that a distinct feature of the IC model is that it relies on the Supervisory Attentional System (SAS) component from Norman and Shalice's (1986) model of executive control. The SAS is responsible for regulating actions when they do not fall into routine behaviour, and is contrasted with the maintenance of well-practiced behaviour. Each action sequence, or schema, is the product of a familiar routine under operation all the while being supervised by the SAS that intervenes when a slip in action occurs. Green (1998) adopts the idea of schemas into the IC model to include language sequences such as translating between languages, writing an essay, or reading a word. Depending on the intention of the speaker, the SAS will retrieve the relevant language schema from memory and implement it within the language system, which is Kroll and Stewart's (1994) model of the bilingual lexicon. Once this has been established, the schema controls the activation of lemmas through inhibitory control to ensure that the correct lexical representations are selected.

At each level of inhibitory control – lexical and language task – the IC model makes different predictions on language behaviour. In Chapter 3, we considered the consequences of the IC model at the lexical level which was that bilinguals relative to monolinguals should show an advantage in general-domain tasks of inhibitory control given the massive practice they have had in engaging the SAS. We concluded then that further evidence was needed to support the claim that language control, defined as the suppression of interference, was subsidiary to executive control. In the present chapter, we consider the prediction that the IC model makes at the language level: bilinguals will experience a language *switch cost* in proportion to their language proficiency when switching between their languages.

The language switch cost

The language switch cost is defined as the time it takes for bilinguals to switch into a different language compared with staying in the same language of response. For example, English-Mandarin bilinguals speaking in English may choose to continue speaking in that language, or they could switch to Mandarin. On the surface, this appears to be a mundane episode. After all, there is no reason why saying *let's eat some <u>veg</u>* should be any different from *let's eat some <u>cai</u>* ("vegetables" in Mandarin). However, under laboratory-controlled settings, the act of switching into *cai*, rather than continuing with *veg*, would have revealed a time cost for switching into Mandarin, or a Mandarin switch cost. Similarly, if the situation occurred the other way, with bilinguals speaking in Mandarin first and then switching into English, an English switch cost would have been incurred.

According to the IC model, this cost is based on the idea that in order for an unused language to be realised into speech, it first needs to be unsuppressed. The process of unsuppressing a target language and then using it consumes time, compared with simply remaining in the previous language of use. What then, determines the time taken to unsuppress a to-be-used language? In Chapter 2, it was explained that the suppression imposed by the SAS on language units is reactive. This implies that for any language that is irrelevant, the amount of suppression applied to it is determined by how strongly activated that language is. By this, Green (1998) refers to the proficiency of a language. It also implies that bilinguals who are more proficient in one language than the other, will have to apply different amounts of suppression to the unused language. Accordingly, when not in use during bilingual discourse, the stronger language will be more greatly suppressed than the weaker language.

The consequence of this is that if a bilingual decides to switch from speaking in the weaker language to the stronger language, more time will be needed to access the stronger language (due to the amount of suppression) than if the switch was in the reverse direction. In other words, the IC model leads to the counterintuitive prediction that of their two languages, unbalanced bilinguals will be *faster to switch to the weaker language* compared with switching to the stronger language. Thus, switch costs of the weaker language (i.e., L2) are predicted to be smaller than switch costs of the stronger language (i.e., L1). In the literature, the demonstration of this *asymmetry* in switch costs is taken to be an index of the involvement of executive inhibition in language switching. Another way of viewing this is that language control, that consists primarily of suppression according to Green (1998), is no different than task control.

Before reviewing studies that have examined language switch costs, we lay out the experimental paradigm that language switching is based on. This is the cued task switching paradigm.

The Cued Task Switching Paradigm

Research in task switching focuses on the study of executive control. In Chapter 3, this was introduced as the ability to adapt to novel situations. If executive control oversees the ability to adapt to changing situations, a suitable paradigm is one that allows for a contrast between participants reacting to a change in situation, and them remaining in an unchanged one. This enables researchers to partial out the behavioural processes involved in a change in situation. The cued task switching method achieves this by inducing participants to switch between two tasks. Each task comprises a configuration of task-relevant processes known as a *task set* (Kiesel et al., 2010; Monsell, 2003). During an experiment, participants are presented with a series of stimuli, each accompanied by a cue indicating the task to be performed (Figure 9).

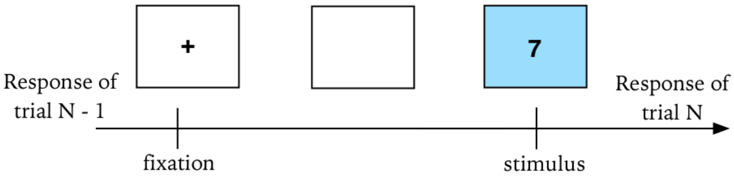


Figure 9: Schematic of the cued task switching paradigm used in a task where participants have to judge if the number is odd or even (parity task) or big or small (magnitude task). Shown in the figure is trial N where a blue background cues the parity task. If a blue cue appears again, trial N+1 is a ***repeat*** *trial. If a different coloured cue appears, trial N+1 is a* ***switch*** *trial.*

After participants complete a task, the task may repeat in the following trial, or if a different cue indicates for a change of task, then the task will switch. Trials where the task repeats are *repeat trials*, and trials where a change of task occurs are *switch trials.* For each participant, the contrast between the median time taken to perform switch trials and repeat trials yields the median time cost it takes to switch into a new task set, the task switch cost. Thus, for any particular sample, the mean of the median task switch cost RT is a reflection of the processes involved in a change in behaviour.

The working assumption in language switch research is that since a task switch cost reflects the processes required for a change of task, then the language switch cost reflects the processes required for a change in language (Abutalebi & Green, 2008; Meuter & Allport, 1999). In this way, the study of language control builds on the task switching paradigm. In the language switching paradigm, a cue signalling the language of response accompanies a to-be-named picture stimulus. Contrasting two-trial sequences where a language switch occurs against sequences where a language repeats itself results in a language switch cost. The IC model specifies these processes to reflect the suppression that is applied to each language.

To illustrate how language switch costs are calculated, we return to the example of English-Mandarin bilinguals. Switch costs are dependent on the idea that it takes a longer time to switch into a new task than to remain in the same one, therefore each cost is derived from a baseline. Naturally, the baseline for English switch costs are English repeat trials, where the time taken to respond in English following a last response in English represents this measure. Switching into English necessitates that the preceding trial was in Mandarin. Thus, specifically, the median time taken to switch from Mandarin to English minus the median time taken to repeat in English produces the median English switch cost RT. Accordingly, the Mandarin switch cost is calculated as the median time taken to switch from English to Mandarin minus the median time taken to repeat in Mandarin. If English switch costs are not significantly different from Mandarin switch costs, they are said to be symmetrical. By the same token, if the switch costs of one language is greater than the other, the pattern of switch costs is then asymmetrical.

The reason we refer to the median instead of the mean is to protect our data from outliers. In an effort to accurately depict the language switching ability of balanced and unbalanced bilinguals, in our experiments, we use an array of 260 picture stimuli where others have previously kept to a range of 10 (Costa & Santesteban, 2004) to 48 (Verhoef, Roelofs, & Chwilla, 2009). However, this makes our data vulnerable to unintended behaviour such as participants attempting to guess a picture name if it is unknown. Therefore, following Monsell and Mizon (2006), we use the mean of median RT to calculate the switch trials, repeat trials, and switch costs of our sample.

Behavioural Evidence

As was alluded to earlier, the first study that provided evidence for the IC model was independently conceived from language switching research. Meuter and Allport (1999) observed an asymmetry of switch costs in task switching studies where participants took more time to switch into the stronger task than the weaker task (Allport et al., 1994; Allport & Wylie, 2000). Based on this finding in the task domain, Meuter and Allport investigated whether this phenomenon could be extended to the language domain. They tested unbalanced bilinguals who spoke English (L1) and an additional language (L2) on a numeral-naming task. A series of Arabic numerals 1 to 9 were presented one at a time on a monitor. Each numeral was superimposed on a coloured rectangle, in blue or yellow, which indicated the language of response for that particular numeral. Altogether, there were four types of two-trial sequences. These were L1 repeat trials, L1 switch trials, L2 repeat trials, and L2 switch trials. By contrasting the switch and repeat trials of each language, Meuter and Allport found that the L1 switch cost, that is, switching from L2 to L1 relative to repeating L1, was greater than the L2 switch cost, which would be switching from L1 to L2 relative to repeating L2. This confirmed the hypothesis that unbalanced bilinguals would yield language switch costs of asymmetrical proportions, in accordance to their language dominance. Importantly, their results also suggested that language was not a specialised function separate from other cognitive processes, and was subsidiary to the same control mechanisms as other non-language functions are.

This switch cost asymmetry in unbalanced bilinguals has been replicated in several studies. In the first experiment of a series of five experiments, Costa and Santesteban (2004) ran a version of Meuter and Allport's (1999) experiment with two kinds of unbalanced bilinguals, one Spanish-Catalan and the other Korean-Spanish. The researchers used 10 to-be-named picture stimuli that were randomly presented for a total of 950 trials. Both groups of bilinguals took longer to switch into their more proficient language, showing that the asymmetrical cost was generalizable to different types of bilinguals as well as stimuli. Jackson et al. (2001), like Finkbeiner, Almeida, Janssen, & Caramazza (2006, digit-naming data for Experiments 1 and 2), also found asymmetrical switch costs incurred by unbalanced bilinguals during numeral-naming under language switching conditions. Philipp, Gade, and Koch (2007, Experiment 1) reported particularly supportive results in a novel study that tested unbalanced bilinguals with a weak third language (L3). These participants afforded the unique combinations of L1, L2, and L3 pairings to observe switch cost magnitudes. The authors managed to show that switching into L1 took longer than switching into L2, which in turn took longer than switching into L3. As a further test of the IC model, Costa and Santesteban reasoned that balanced bilinguals should show *symmetrical* costs, since they were equally proficient in two languages. To test this logic, Costa and Santesteban ran a second experiment on balanced Spanish-Catalan bilinguals. They used the same experiment as they did on the unbalanced Spanish-Catalan and Korean-Spanish bilinguals. True to expectations, balanced bilinguals took as much time to switch into Spanish, as they did to switch into Catalan.

So far, the evidence was consistent with the IC model, indicating that the inhibitory component of executive control reactively suppressed the language that was not in use. These studies also illustrated the usefulness of language switch cost symmetry and asymmetry in indicating the involvement of inhibitory control. There were, however, two difficulties with extending these results to firmly peg language switching behaviour as one that was under the control of executive processes. First, there was a body of research showing more complex switch cost patterns that the IC model could not account for. Second, the diversity of methods used and focus of each study in this research did not lend cohesion across results (even though all studies examined the language switch cost symmetry and asymmetry). Given this pattern, this brought into question as to whether switch cost patterns should be the only focus of language switch studies. In the following paragraphs, we review this research, some of which raise further questions, but nevertheless represent an effort to take language switch research in a different direction.

In their fourth experiment, Costa and Santesteban (2004) showed results contrary to the predictions of the IC model. They found symmetrical switch costs in balanced Spanish-

Catalan bilinguals who were asked to switch between their L1 and a weaker L3. If the language suppression account was correct, a switch from L1 to L3 (henceforth denoted as "L1/L3") should take a shorter time than a L3/L1 switch. Costa et al. (2006, Experiment 2) followed up on these results testing a different group of bilinguals, again balanced in L1 and L2, but weak in L3. The same picture-naming task comprising 10 picture stimuli was administered. Results of this experiment showed no differences between L1/L2 and L2/L1 switches as was expected, but replicated the unexpected symmetrical costs in L2/L3 vs. L3/L2 switches. In yet another study, Calabria et al. (2012) replicated the symmetry, finding no differences in L1/L3 and L3/L1 switches. It appeared from this set of experiments that balanced bilinguals did not show asymmetrical costs. Costa et al. (2006, Experiment 3) tested a stronger version of the hypothesis that balanced bilinguals did not show asymmetrical costs and ran the same picture-naming experiment on balanced bilinguals who spoke a weak L3 and an even weaker L4. This time, an asymmetrical pattern as predicted by the IC model was shown, with L4/L3 switches taking longer than L3/L4 switches. Costa et al. (2006, Experiment 4) then tested balanced bilinguals and monolinguals in a novel switching task. Participants had to switch between their native language and 10 made-up words. The made-up words supposedly represented the learning of a new language and thus were weakly formed lexical representations. Both balanced bilinguals and monolinguals took more time to switch into L1, compared with switching into the new language, showing that balanced bilinguals could show asymmetrical costs as unbalanced bilinguals did.

With all the above evidence, Costa et al. (2006) concluded that firstly, the asymmetrical pattern derived in switching between L3/L4 and native/new language showed that there were circumstances under which balanced bilinguals would resort to the same inhibitory mechanism as unbalanced bilinguals. This could be explained by the IC model. Secondly, on the basis of symmetrical costs shown in L1/L3 vs. L3/L1 switches, balanced bilinguals had access to a different sort of mechanism from unbalanced bilinguals. What mechanism could explain balanced bilinguals' similar language switching behaviour between two languages with disparate proficiencies?

Costa et al. (2006) appealed to a language-specific selection and proposed that this selection process was applicable only to languages that were sufficiently integrated into the lexicon. That is, in Costa et al's (1999) description, the selection mechanism was "blind" to lemmas of the unneeded language. Therefore, when choosing between L1, L2, and L3, words from the unneeded language at any point in spoken discourse were not considered for selection, and thus, response output was unaffected. A separate case was made for lemmas of a language with extremely weak lexical links, such as one's L4 or a newly learnt language. In these languages, there was hardly an adequate representation of forms that could make up what one would call a lexicon. Under this circumstance, there was no lexicon to speak of that a language-specific mechanism could act on, and therefore when switching between L1 and a very weak language, the secondary inhibition selection process as proposed by Green (1998) took over. This would be that lexical representations from both languages were considered in the selection process; the stronger the irrelevant words were, the more strongly they were suppressed, hence giving rise to asymmetrical costs in L3/L4 and L1/new language switches.

Costa et al's (2006) explanation remains to be tested with more independent samples, although the findings of one study that claimed to show language-specific selection effects in unbalanced bilinguals is inconsistent with their interpretation (Costa & Caramazza, 1999). Nonetheless, the contribution of Costa and Santesteban's (2004) series of experiments was to show that it was possible for the same group of bilinguals to show both symmetrical and asymmetrical switch costs.

Philipp et al. (2007) ran a numeral-naming language switching study that recruited unbalanced bilinguals with a weak L3. The purpose of the study was to examine the magnitude of asymmetrical switch costs in pairs of languages with different proficiencies. Given that the switch cost was determined by how easily unsuppressed a switched-into language is, and since unbalanced bilinguals possessed a clear dominance in L1, a less proficient L2, and a considerably weaker L3, the difference in the time taken to unsuppress L1 and L2 would be smaller than the difference in the time taken to unsuppress L1 and L3. Therefore, by examining the size of asymmetry, Philipp et al. were in a position to indirectly test the claim, from a within-subject standpoint, that switch costs were directly related to language proficiency. Three language-switch pairs were considered. These were L1/L2, L1/L3, and L2/L3. L1/L2 and L2/L3 switches were expected to incur asymmetries of similar sizes, while L1/L3 was expected to show the largest asymmetry. General analyses showed expected switch cost asymmetries in each language-switch pair, but did not find significant differences in the size of asymmetry between the language pairs. The results of Philipp et al. indicated that unbalanced bilinguals did not always show switch cost magnitudes corresponding to language proficiency, indicating that their pattern of inhibition may not be as straightforward as predicted by Green (1998), even though the unbalanced bilinguals in their group showed switch cost asymmetries.

In line with Philipp et al. (2007), Finkbeiner et al. (2006) disagreed that switch costs reflected language dominance effects. They stressed that switch costs were a result of task-specific characteristics and identified two kinds of characteristics associated with task stimuli that could determine switch costs. The first task characteristic was the number of responses that were mapped to a stimulus. The authors argued that in tasks where subjects switched between stimuli that afforded two responses on each trial (bivalent stimuli), switch costs were robust compared with when subjects switched between trials that had only one response option (univalent stimuli). For example, the authors believed that if participants were shown a randomized series of words and digits, and were instructed to always read words in English and name digits in Mandarin, they would be switching between univalent stimuli and would not show costs. As support for their argument, they cited the study by Allport et al. (1994) where participants switched between colour-naming and counting, and had not incurred any costs. In language switching studies for which stimuli are mapped to two language options, switch costs are always incurred. Therefore, switch cost patterns seen thus far could be a result of stimulus valency.

To separate the contributions of switching between bivalent and univalent stimuli, Finkbeiner et al. (2006) presented a series of pictures and digits to unbalanced bilinguals, and instructed them to name digits in L1 or L2, but to name pictures only in L1. This way, digit stimuli were bivalent, and picture stimuli univalent. Switching between L1 and L2 in digit-naming simulated conventional language switching trials (bivalent to bivalent), but switching from digit-naming to picture-naming (bivalent to univalent) would demonstrate a switch to a trial that required only one kind of response. To analyse their results, they extracted all digit-naming trials from the mixed task context and found the classic asymmetrical switch cost pattern where L1/L2 switches were quicker than L2/L1 switches.

The conditions of interest were switch trials that led to L1 picture-naming for which Finkbeiner et al. (2006) had predicted no costs would be shown. Two kinds of univalent trials were possible. These were L1 digit naming/L1 picture-naming where the language repeated, and L2 digit naming/L1 picture-naming where a language switch occurred. Both these sequences did not elicit switch costs as predicted by Finkbeiner et al. (2006) and confirmed the researchers' claim that valency of a task stimulus was instrumental in generating switch costs. Switch cost effects could then be a result of having to suppress competing responses in each trial and where no competing options were offered in univalent stimuli, no costs would be incurred. A problem with this account, however, is that it has overlooked the fact that the sequence of naming a digit in L1 and then a picture in L1 is confounded by a change in task, even if the language remains the same. This means that the authors could have been comparing two different task switch situations – one where the stimulus changes, and one where the language of response changes. This makes it difficult to interpret their set of findings with confidence.

The second task characteristic Finkbeiner et al. (2006) identified as a confound was the availability of a response to a speaker. They claimed that the inhibitory mechanism may be suppressing lexical representations according to their availability; the more available a response was, the faster it would be accessed and the stronger it would be suppressed if irrelevant. By this account, distinguishing between L1 and L2 words via a tagging feature (Green, 1998) would be unnecessary since selection and suppression was made on how quickly (or easily) each lemma was accessed. To test this hypothesis, the researchers designed a set of stimuli that comprised words that would be named quickly and words that would be named slowly. For example, on the basis of established word frequency, length, and number of possible meanings, *cat* was expected to be read more quickly than *kitten*, *small* was expected to be read more quickly than *tiny*, and so on. To ensure that 'fast' words were not more highly activated than 'slow' words during the experiment, the researchers presented the word stimuli in red, green, yellow, or blue, so that participants were to switch between colour-naming and word-naming, based on a background cue. It was expected that a fast- or slow-word would not influence colour-naming latencies, or colour-naming switches. To simulate an L1/L2 or L2/L1 switch, the order of fast-words and slow-words was manipulated to yield fast/slow and slow/fast sequences.

The predictions Finkbeiner et al. (2006) made were supported by their results: word type did not affect colour-naming and word-naming, and participants took more time to switch into naming fast-words than slow-words. That participants showed a switch cost based on word-retrieval rates suggested that a core feature of the IC model, which is selection and suppression of lexical representations via language membership tags, was unnecessary in accounting for asymmetrical switch costs. This is a plausible alternative to explain language switch costs although it is not fatal to the IC model, since retrieval speeds are acknowledged to be a characteristic reflecting language proficiency.

More recent work focusing on balanced bilinguals has shown that they display the symmetrical switch cost pattern in L1/L2 and L2/L1 switches although the tasks used in these studies depart greatly from the traditional task type. For example, Tarlowski, Wodnieka, and Marzecova (2013) used pictures to elicit verbs in L1 and L2, and Macizo, Bajo, & Paolieri (2012) presented L1 and L2 words on the monitor that required categorising into a "living" or "nonliving" class, by keypress. These studies contribute to the repertoire of task types employed in language switching. However, since the incidence of switch costs has been made on the case of different language proficiencies with a strong emphasis on conceptual processing and lexical retrieval, it is not clear how responding in verbs, belonging to the domain of grammatical structures, relate to the theoretical basis for switch costs. Similarly, the demonstration of symmetrical switch costs incurred by categorising words is ambiguous as this taps into word recognition processes rather than lexical access. Given that word recognition and lexical access are based on different models (e.g., Dijkstra & Van Heuven, 2002 vs. Green, 1998), the findings of Macizo et al. (2012) require further clarification if they are to be considered within current research.

Summary and task switch development

Aside from recognising that language dominance and inhibitory control may play a key role in predicting switch cost patterns, little progress has been made with regard to understanding the underlying processes of language switching. What appears to be more certain is that a cost is always involved when there is a switch in language (e.g., Jackson et al., 2001), and that comparisons of both balanced and unbalanced bilinguals can yield insights into language control (Calabria et al., 2012; Costa & Santesteban, 2004). Symmetrical and asymmetrical switch cost patterns have been important in revealing the different circumstances under which inhibitory control as described by the IC model operates. At the moment it appears that the language switch cost may be sensitive to the degree of bilingualism (Costa & Santesteban, 2004; Costa et al., 2006), stimuli type (Declerck, Koch, & Philipp, 2012; Finkbeiner et al., 2006) and language pairings (Philipp et al., 2007). The methodology of some of these studies raise some potential problems but the important point is that a narrow focus on switch cost patterns does not get us very far in elucidating the language switching process.

In contrast to the state of language switching, non-language task switch research has steadily advanced. An area that has seen a lively debate over the years, and that has helped to push forward task switch research, is the search for the source of the switch cost (see Kiesel et al., 2010, and Monsell, 2003). The literature on this can be broadly split into two views. In the first view, researchers believe that the cost of switching is due to an “inertia” of a previous task set that is carried into an existing trial (Allport et al., 1999). In the second view, the cost of switching is believed to reflect the time needed to reconfigure the mental settings in an existing task set to suit a new one (Monsell & Mizon, 2006; Rogers & Monsell, 1995). It is likely though that the switch cost is influenced by a combination of both accounts (Goschke, 2000; Monsell, 2003).

In addition to this, a development in the task switch domain highlighting a fundamental methodological flaw in the switching paradigm raises further questions as to what task switch data really reflect (Logan & Bundesen, 2003), thereby directly implicating language switch data. This problem, which relates to the use of cues in the switching paradigm, is currently being tackled by task switch researchers (Arrington, Logan, & Schneider, 2007; Logan, Schneider & Bundesen, 2007; Monsell & Mizon, 2006).

In the next section, we outline the theories of *task set inertia* and *task set reconfiguration*, and follow this up with their application in language switch research. The latter part of the section addresses the methodological problem of cue design in the task switch paradigm.

Task set inertia

Task set inertia was proposed to account for the paradoxical switch cost effect seen in participants when switching between two cognitive tasks. It was well-known that when faced with a colour name printed in a different colour ink, participants encountered difficulty in naming the colour compared with naming the word (see MacLeod, 1991). When instructed to switch between colour-naming and word-naming, switching into the more difficult task took a shorter time than switching into the easier task. This had been confirmed in tasks using Stroop-like stimuli (Allport et al., 1994 and see MacLeod, 1991), digit-naming stimuli (Meuter & Allport, 1994), and picture-naming stimuli (Jackson et al., 2001). In these experiments, the tasks of different strengths were paired. The strength of a task could be said to be the degree to which a response was associated with a particular stimulus. A stimulus-response (S-R) mapping was typically strengthened by constant practice, so much so that some S-R mappings, for instance, to decode a word upon visual contact, became what some might describe as automatic.

Task set inertia theory stated that the stronger the irrelevant task was, the greater the amount of inhibition that was needed to suppress it so that the relevant weaker task might proceed. This strong suppression of a task set was taken as a form of interference that was carried over to the next trial, and interfered with performance of the current task. If the suppressed task became relevant again, a time cost would result in having to overcome its suppression.

This explanation drew a striking similarity to language switch costs which were dependent on language proficiency; links between lexical representations and their concepts were strengthened through continual use of the same language to the point that native-like fluency was attained. Since the IC model and task set inertia theory were both reliant on reactive suppression as a key process, the two frameworks converged on the same prediction, which was, switching from a difficult to an easy action was more costly than if the switch were reversed. As a result of their theoretical overlap, in testing the IC model, language switch researchers also noted that their experiments directly addressed task set inertia theory (Philipp et al., 2007).

The considerable number of language switching studies demonstrating the switch cost asymmetry seen in tasks of different strengths, in languages of different proficiencies, gave language switch researchers the confidence to posit that language switching was not different from task switching. In other words, to speak of language control would be unnecessary since it referred to executive (inhibitory) control. However, as discussed above, the switch cost asymmetry may be limited in what it could tell us about language control and was but one indication that language tasks may behave like non-language tasks. What remained uninvestigated in language switch studies was a separate aspect of task set inertia. Specifically, Allport et al. (1994) indicated that the task set inertia was likely to be a *passive* process. That is, the “inertia” carried over from a previous trial and into the current trial dissipated as the trial duration lengthened. The authors wrote that the task switch cost “reflects a kind of proactive interference from competing S-R mappings with the same stimuli, persisting from the instruction set on the preceding trials” (p. 436). To demonstrate this property of task sets, Allport et al. (Experiment 5) manipulated the length of the interval between the last response and the next stimulus, and instructed participants to alternate between two tasks. They showed that as the waiting period following the last response increased, participants were quicker to switch into a new task on the next trial, indicating that interference from the previous task set dissipated while participants waited. Therefore, an effect of task set inertia was that switch costs decreased as the time between the last response and the next task increased.

There was, however, an important assumption that had to be made in task set inertia. To unequivocally attribute the decrease in switch costs to a dissipating component from the previous trial, participants could not engage other processes on the next trial. This would then make it possible to assess activation that was carried over from the previous trial, into the current trial, without foreign influences. The task-alternation design used by Allport et al. (1994) made task switches predictable, therefore participants could have anticipated the next trial and begun preparing before the onset of the stimulus. Thus, it was not guaranteed that participants had maintained their task settings from the previous task set into the current trial. Meiran et al. (2000, Experiment 1) solved this problem by making switches unpredictable, and separated the task switch procedure into two components, the response-cue interval (RCI) and cue-stimulus interval (CSI) (Figure 10).

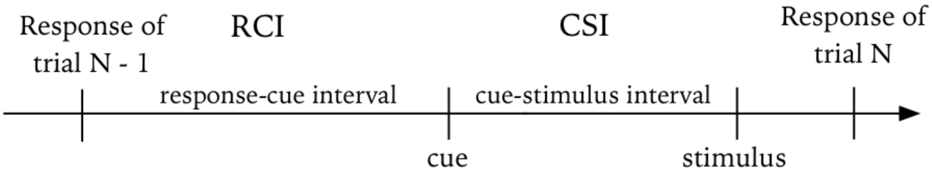


Figure 10: Schematic of a variation of the cued task switch procedure with the cue preceding the stimulus. The response-cue interval (RCI) is believed to contain activation carried over from trial N-1, while the cue-stimulus interval (CSI) reflects the amount of time available to prepare for trial N.

With no knowledge of the upcoming task available prior to the cue, it was unlikely that participants would engage new task settings following a response. After the cue appeared, this task set state may not be maintained. Meiran et al. ran a task switching experiment using this procedure and varied the RCI at five intervals, ranging from 132 ms to 3,032 ms, while keeping the CSI constant at 117 ms. By keeping the CSI constant and short, Meiran et al. ensured that RT of switching into a task could be attributed to the influence of the RCI, but also allotted sufficient time in the CSI for the cue to be encoded. Consistent with the predictions of task set inertia, the results of the experiment showed that as the RCI increased, switch costs decreased. These results were corroborated by Koch (2001) who found smaller switch costs when the RCI was 900 ms than when the RCI was 100 ms, while keeping the CSI at 100 ms.

Task set reconfiguration

In contrast to suppression processes, Rogers and Monsell (1995) suggested that when participants switched into a new task, as opposed to staying in the same task, the switch cost incurred arose from having to implement a change in task settings to prepare for the new task, much like mental “gear-changing” (Monsell, 2003, p. 135). This *task set reconfiguration* required an internal change to task settings that were configured to the previous trial, to be reconfigured to the current trial. Therefore the assumption in this model was that participants reconfigured their task sets after the cue appeared, and only if the cue indicated a change of task. It followed that if participants were given sufficient time to complete reconfiguration processes, they would be better prepared to perform the upcoming task. Therefore, evidence of task set reconfiguration would come from the examining the preparatory effect in task switching – switch costs would decrease as the time available to prepare for the next task increases.

Rogers and Monsell (1995) approached this by designing a task switch paradigm to make explicit to participants when a task switch would occur, so that participants could prepare in advance of an upcoming stimulus. They varied the trial duration at a range of 150 ms to 1,200 ms to manipulate preparation time. The computerized task entailed switching between deciding whether an alphanumeric character such as “G7” contained a vowel or consonant, or an odd or even number. On each trial, an alphanumeric stimulus would appear in a cell of a 2 × 2 square grid. The display of the stimulus in the cell proceeded in a clockwise fashion so that participants worked through the top row from left to right and then the bottom row from right to left over the course of four trials, and the cycle would repeat.

The instruction was to respond to the alphabet when the stimulus was on the top row, and to respond to the number when the stimulus appeared in the bottom row. With this setup, participants had a salient way of tracking stimuli appearance within the 2 × 2 grid and could anticipate a task switch when stimuli appearance changed rows, or a task repeat when stimuli remained in a row. The results showed that switch costs reduced as trial duration increased – a preparatory effect – with the sharpest reduction occurring up to a trial duration of 600 ms interval, after which they steadily reached an asymptote at the longer durations.

In the same paper criticizing Allport et al's (1994) methodology, Meiran et al. (2000) pointed out that the paradigm used by Rogers and Monsell (1995) suffered from the same experimental weakness as Allport et al. which was that RCI effects were confounded with CSI effects. Without a clear demarcation to indicate when participants began preparing in a task, the reduced switch cost effect may have partly been the result of carryover activation from the previous trial. A more conservative approach would be to isolate the effects of preparation. Using the same procedure in shown in Figure 10, Meiran et al. varied the CSI over a range of values and kept the RCI constant in each block. The assumption was that participants were only able to begin preparing after the cue appeared. If they made use of the remaining time available to reconfigure towards the new task, then the time taken to switch to a new task should reduce as the CSI increased. Results of this experiment indeed showed a reduction in switch costs over an increasing CSI, giving support to task set reconfiguration theory.

This preparatory effect of task set reconfiguration – a decrease in switch costs as the CSI increased – was taken to be an index of executive control processes necessary to implement a change in task.

Language Switching Evidence

Task set inertia and task set reconfiguration offered novel ways of investigating language switching. Both views predicted the phenomenon of reduced switch costs over an increasing interval, but reflected very different processes. A reduction of switch costs over an increasing RCI was believed to reflect a dissipating component from the previous trial while the same phenomenon seen over an increasing CSI was believed to reflect preparation processes. To our knowledge, four language switching studies have directly or indirectly examined CSI processes but none have studied RCI processes. Except for Costa and Santesteban's (2004) fifth experiment (Table 1), none of these studies clearly tested for task set inertia or task set reconfiguration processes.

Table 1
Overview of language switching studies which have varied the response-cue interval (RCI) or cue-stimulus interval (CSI). TSI – task set inertia; TSR – task set reconfiguration.

Study, Experiment	Bilingual type, switch cost pattern	RCI (ms)	CSI (ms)	TSI? TSR?	Stimuli
Costa and Santesteban (2004), Experiment 5	Balanced, unreported	1,150 1,150 1,150	0 500 800	TSR	10 pictures
Verhoef et al. (2009), Experiment 1	Unbalanced, asymmetrical	1,500-2,300	500	TSR	48 pictures
	symmetrical	1,500-2,300	1,250		
Philipp et al. (2007), Experiment 1	Unbalanced, asymmetrical	1,000 100	100 1,000	both possible	digits 1 to 9
Declerck et al. (2013), Experiment 1	Unbalanced, unreported	0 0 0 0 0 0	900 1,100 1,300 1,800 2,000 2,200	none	weekday names in order from Monday to Sunday

In an earlier mentioned study conducted by Philipp et al. (2007) which examined switch costs of unbalanced bilinguals who spoke a weak L3, as a secondary aim, Philipp et al. had also probed the influence of the CSI on language switch costs. The bilinguals switched between L1, L2, and L3 in a digit naming task under a short CSI condition of 100 ms and a long CSI condition of 1,000 ms. Philipp et al. found no effects of task set reconfiguration. Instead, switch costs were surprisingly larger at the long CSI than short CSI. Why should a longer preparatory time increase switch costs? Philipp et al. suggested that the preparation of a language-defined set might differ from a non-language-defined set. In their paper however, Philipp et al. did not make clear what a "language-defined set" was, nor did they specify how preparation might differ from a non-language set. Similar to previous studies that had confounded the RCI with the CSI, the researchers' experimental design might explain their results. The authors had kept the trial duration constant at 1,100 ms, which meant that when the CSI was short, the RCI was long, and when the CSI was long, the RCI was short. Therefore, the increase in switch costs at a long CSI vs. a short CSI, may be interpreted as that occurred at a short RCI vs. a long RCI. That is, switch costs reduced as the RCI increased. This then would be consistent to task set inertia theory which held that dissipation of a completed task reduced interference in a present switch trial.

Declerck et al. (2013) carried out a language switching study with predictable sequences and found numerical decreases in switch costs at longer CSI conditions compared to short CSI ones. The decrease however was not significant, indicating that no task set reconfiguration had taken place. Additionally, the experimental paradigm used by Declerck et al. was substantially different from conventional language switching, which did not make their results easily extendable to other studies. In Declerck et al's study, participants were instructed to alternate between their languages (L1-L1-L2-L2-L1-L1, and in reverse order) and name the days of the week, in the order from Monday to Sunday, each time an auditory tone was buzzed. Therefore the first difference from the conventional language switching paradigm was that switching speed was self-paced, with L1 and L2 responses given in 7-word sequences. This implied that participants knew at which point in each sequence a switch occurred and could have memorized the string of L1 and L2 weekdays as a phonological chunk in working memory. Responses could then have been based on switching between different phonological codes, or were an effect of recitation. The next difference was that in requiring participants to retrieve the names of the week in advance, Declerck et al. took "predictable" to mean a foreknowledge of the to-be-named concept. In previous predictable paradigms, the to-be-named concept was always concealed, but the cue provided a foreknowledge of the to-be-performed task (Rogers & Monsell, 1995) or language (Philipps et al., 2007).

Costa and Santesteban (2004, Experiment 5) provided the first evidence of task set reconfiguration in language switching. Using experimental parameters similar to Meiran et al. (2000), they demonstrated a reduction in switch costs as the onset of the stimulus was delayed. Since the RCI was kept constant, the reduction in switch costs could be attributed to the influence of the varying CSI.

Verhoef et al. (2008) provided somewhat similar evidence in their neurophysiological study, with clear switch cost reductions at long CSIs, but certain aspects of the methodology again raised questions about the generalisability of the study's results. The first was that their experiment was unusually long. Participants performed a picture-naming task over 16 blocks which each took 8 minutes to run, totalling to about two hours to perform the task. Including the time taken to prepare participants with special equipment such as applying electrodes to participants' heads, documenting participant profile, and giving allotted breaks, the experimental session lasted about four hours, as reported by the researchers. The next was that the participants, who were unbalanced bilinguals, familiarized themselves with the picture-naming stimuli before the experiment. This would have given them the opportunity to strategize dealing with less familiar pictures in their weaker language. Given that part of the aim of the study was to study task set reconfiguration, this step may have assisted in "pre-preparing" the unbalanced bilinguals to respond in their weaker language. An idiosyncrasy was that the researchers took the CSI value (750 ms or 1,500 ms) as the combined duration of the true CSI (500 ms or 1,250 ms) and stimulus duration (250 ms). This did not affect data interpretation but may be misleading when reported in other studies (Bobb & Wodniecka, 2013) to give the impression of effects of a longer CSI than was carried out in the experiment. Nevertheless, there was a notable result – unbalanced bilinguals showed symmetrical and asymmetrical switch cost patterns, a behaviour that was once reported in balanced bilinguals (Costa & Santesteban, 2004). In this experiment, unbalanced bilinguals showed asymmetrical switch costs at a short CSI, and symmetrical switch costs at a long CSI, suggesting that switch cost patterns were sensitive to trial durations.

From the above, except for Costa and Santesteban's (2004) experiment, there was no clear pattern of dissipation or preparatory effects in language switching. Philipp et al. (2007) and Verhoef et al. (2009) confounded the RCI with the CSI while the language switching paradigm used by Declerck et al. (2013) deviated greatly from the rest such that drawing larger implications from their data was futile. At this point, it is worthwhile reiterating the assumptions of task set inertia and task set reconfiguration, both of which have so far been more effectively examined with the paradigm used by Meiran et al. (2000) (Figure 10). These are:

(a) participants do not reconfigure for a task set until the cue appears

(b) participants reconfigure their task set only when the cue indicates a task change

A violation of (a) would confound switch trial RT and (b) would confound repeat trial RT, both of which would lead to misleading interpretations of the magnitudes of switch costs. Therefore, as a precaution, in addition to using a suitable paradigm, participants should be encouraged to maintain (a) and (b). Overall, in the language switching studies reviewed so far, a problem was that the RCI and CSI had not been used to their methodological advantages.

Despite the work that needed to be done in language switching with regard to the RCI and CSI, there was another immediate problem. What if it could be shown that language switch data may not reflect a change in language processes, but were an effect of cue switches? In the final section of this review, we look at this problem.

Cue Effects

Logan and Bundesen (2003) reported a methodological flaw in task switch studies and cautioned against drawing conclusions from findings which might be the result of a separate agent. They pointed out that in using one cue to signal one task, it was impossible to deduce that switch costs were a result of task switches. Consider the two possible trial types, switch trials and repeat trials. After completing a task, the same cue may appear again, indicating a repeat trial. Alternatively, a different cue could appear and indicate a change of task. Hence, when the cue repeats, the task repeats. When the cue changes, the task changes too. How could researchers be assured that switch cost data reflected task switches and not cue switches, if every change of task was shadowed by a cue switch?

Logan and Bundesen (2003) approached the issue by assigning two cues to one task. This made it possible for a task to repeat itself, but yet be signalled by a different cue from the one in a previous trial. In this type of trial, the *cue switched only*, revealing the effects of a change in cue. Thus, “true” switch costs could be obtained by subtracting cue effects from regular switch trials, which would be when the cue and task *both switched*. To show that cue effects did not contribute to RT, trials where the cue switched only could be compared with regular repeat trials where *no switch* in cue or task occurred. If no differences were found between these two types of trials, then effects of a change in cue were negligible. In short, to demonstrate switch costs unconfounded by cue switches, RT from cue-switch-only trials were subtracted from both-switch trials; to demonstrate cue effects, cue-switch-only trials were compared with no-switch trials (Figure 11).

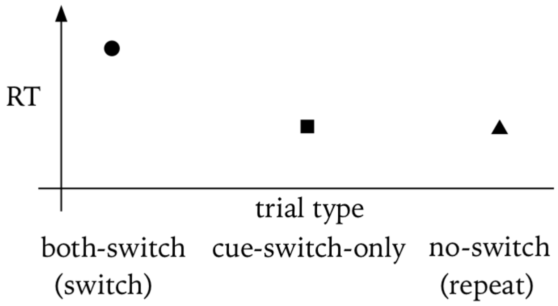


Figure 11: The graph shows the approximate relative RT of both-switch, cue-switch-only and no-switch trials, assuming that cue-switching does not contribute significantly to switch costs. No significant differences are expected between cue-switch-only and no-switch trials, while both-switch RT is expected to be significantly higher than the other two trial types.

Logan and Bundesen (2003) used this 2:1 cue-to-task mapping and instructed participants to switch between judging whether digits were odd or even (parity task), or if they were of high or low value (magnitude task). Two word cues, *parity* and *odd-even* were assigned to the parity task, and two other word cues, *magnitude* and *high-low* were assigned to the magnitude task. Cues appeared simultaneously with digit stimuli and their appearance were delayed over a range of 10 intervals that took values from 0 ms to 900 ms, in 100 ms increments. The RT of each of the three trial types, both-switch, cue-switch-only, and no-switch trials, was traced as trial duration increased. Logan and Bundesen showed that for each trial type, RT decreased as the trial duration increased, indicating that participants found it easier to perform each type of trial as more time was allowed. The two critical results were the comparisons that cue-switch-only trials afforded. First, RT of cue-switch-only trials was as high as both-switch trials. Subsequent analyses revealed no significant differences between the two trial types. This indicated that switch costs were non-significant, and therefore changing into a new task did not take up extra time as was believed. Second, the RT of no-switch trials was significantly lower than cue-switch-only and both-switch trials. This result showed that of the three trial types, participants were quickest to perform trials where the cue and task repeated, and that a change in cue contributed significantly to an increase in RT. In sum, the data reflected large cue change effects while task change effects were negligible. Robust conventional (but confounded) switch costs derived by contrasting both-switch and no-switch trials were shown, but “true” switch costs as shown by contrasting both-switch and cue-switch-only trials were minimal. Based on this result, Logan and Bundesen questioned the assumption that task switch data reflected the extra time an individual took to reconfigure to a new task. In line with their scepticism, several other researchers found significant effects of cue changes (Arrington & Logan, 2004; Mayr & Kliegl, 2003; Schneider & Logan, 2011), raising further questions as to the validity of task switch data.

In response, Monsell and Mizon (2006) showed that the criticism Logan and Bundesen (2003) raised against the task switch procedure could be attenuated. In their second experiment in a series of five, they adopted the same 2:1 cue-to-task mapping so that the ideal relative RT of different trial types as plotted in Figure 11 could be demonstrated. In addition to this, they attempted to show that true switch costs were an effect of task set reconfiguration. Therefore, they varied the time allowed for participants to prepare for an upcoming task by manipulating the CSI at a range of intervals beginning from 150 ms to 1,100 ms. Participants performed different CSIs in different blocks. As anticipated, their RT data showed the desired pattern of minimal differences between cue-switch-only and no-switch trials, and a significant increase in both-switch trials, demonstrating that it was indeed possible to capture true task switch costs, and that cue switches did not contribute much to the cost. Switch costs were also shown to reduce as the CSI increased, demonstrating that task switches were an effect of reconfiguration.

The results of Monsell and Mizon (2006) brought up the question of why Logan and Bundesen (2003) had not managed to find true task switch costs. Monsell and Mizon noted that the participants in Logan and Bundesen’s study switched tasks equally frequently as they repeated tasks. If participants felt that the chances of encountering a change in task was the same as a repeat in task, they may have been equally likely to prepare for a change in task as they were not to prepare for one. This raised the possibility that for half the time, participants may not have waited until the cue appeared to begin reconfiguration, and in doing so, would not have adhered to assumptions (a) and (b) as listed in the previous section. This would explain why Logan and Bundesen could not demonstrate true switch cost effects.

To encourage participants to remain in a present task unless called to switch into a new task, Monsell and Mizon (2006) ran a separate experiment and manipulated the frequency of switching in a block. They instructed three groups of participants to each perform a different block of trials. In the first block, the percentage of switch trials and repeat trials occurred in a ratio of 1:3 (25% switch trials). In the second block, the ratio was 1:1 (50% switch trials), and in the third block this was 3:1 (75% switch trials). This experiment showed that participants who had to switch tasks for 25% of the block incurred the largest switch cost effect, followed by the second group, and finally the third. The pattern of results suggested to Monsell and Mizon that as the probability of a switch in the next trial increased, retaining the task set from the previous trial was not beneficial, which may lead participants to reconfigure away from their last response. Thus, the frequency of having to switch tasks within a block of trials was a likely factor in bringing out true switch costs.

Implications

The work of Meiran et al. (2000), Logan and Bundesen (2003), and Monsell and Mizon (2006) brought to the front key gaps in language switching research. On one level, the body of research motivated by Meuter and Allport (1999) and the IC model showed the importance of examining language switch cost asymmetry. On another level, little was known about the dissipation and reconfiguration of language task sets. Compelling questions as to whether true language switch costs could be demonstrated remain unanswered. The substantial number of language switch studies using equal numbers of switch and repeat trials (e.g., Philipp et al., 2007; Verhoef et al., 2009) further raised the possibility that language switch cost data may really be the result of language cue switching. Even if true language switch costs could be demonstrated, it was also uncertain whether balanced and unbalanced bilinguals would still show switch cost patterns as predicted by the IC model.

To summarize, if language switching research was to move forward, which it could do so by examining CSI and RCI processes, the research had to continue to draw lessons from task switch research. As this chapter showed, there were several issues that had yet to be addressed by the language switch community. Experiments 3A, 3B, and 4 explored these issues, by incorporating the factors listed below:

(a) Matched balanced and unbalanced bilinguals were included
(b) Language switch cost symmetry and asymmetry were used as basic indicators of language proficiency, but it was kept in mind that the same group of bilinguals may show both patterns
(c) Language switch data were revisited with a modified design that took into account cue effects vs. genuine switch cost effects (by using two cues for one task)
(d) A low probability of switch trials was used in the experimental design to ensure that participants did not anticipate a task switch before the cue onset

CHAPTER 5 – EXPERIMENT 1

Overview

Research on bilinguals shows that they excel at ignoring misleading information to attend to a target (Ben-Zeev, 1977; Bialystok & Codd, 1997). Based on evidence demonstrating the influence of the non-target language on target language production (Costa et al., 1999; Costa et al., 2000; Hermans et al., 1998), and the assertion that the non-target language is suppressed for fluent bilingual speech (Green, 1998), Bialystok et al. (2004) reason that in daily communication, bilinguals must constantly be suppressing a competing non-target language. Over time, the practice of suppressing the irrelevant language enhances the general ability to ignore distracting information. Bilinguals should therefore be more skilful at suppressing interfering information than monolinguals. This claim finds support in research demonstrating that bilingual children are better than monolingual children in ignoring language anomalies (Ben-Zeev, 1977; Galambos & Hakuta, 1988; Ianco-Worrall, 1972) and irrelevant non-language information (Bialystok & Codd, 1997; Bialystok & Majumder, 1998).

The assumption that bilinguals have enhanced executive control skill from using an extra language is based on research showing that suppression is needed to manage two competing non-language tasks (Allport et al., 1994). To ensure that performance of the target task remains uninterrupted, the Supervisory Attentional System (SAS) suppresses the non-target task. The SAS was incorporated into the Inhibitory Control (IC) model to explain bilingual language production. Therefore, the IC model considers the suppression of an irrelevant language, or its lemmas, to be no different from the suppression of non-language behaviour. By this account, the bilingual advantage assumes that language selection proceeds from suppressing language competition, and that sufficient practice in suppressing language units enhances general interference suppression. This crucial link between language and non-language behaviour explains why in early studies bilingual children were seen to perform better than monolingual children in tasks of conflict.

A problem with the bilingual advantage seen in children (Ben-Zeev, 1977; Bialystok & Codd, 1997) is that this effect could not be generalised to larger bilingual samples because tasks used on children could not be administered across all age groups. This prompted Bialystok (2006) and Bialystok and colleagues (2004, 2008) to use RT-based means to measure the ability to suppress interference. Their series of experiments showed that bilinguals outperformed monolinguals on the Simon task – a task containing perceptual conflict – and strengthened these researchers' belief in the bilingual advantage. However, not all results have successfully shown this advantage. Evidence of a bilingual advantage in young adults or children has been limited. Other studies report of an advantage seen on tasks with no conflict (Bialystok, 2008; Martin-Rhee & Bialystok, 2008). Yet, the bilingual advantage in older adults is reliable. This pattern of results is simply not consistent with the IC model.

A different approach to this problem has been to examine bilinguals in the ability to suppress interference against a more general form of inhibition known as response inhibition (Bialystok et al., 2008; Martin-Rhee & Bialystok, 2008). This is to establish that bilinguals' unique advantage lie in the skill of interference suppression, and not in other forms of inhibition (see Friedman & Miyake, 2004). Response inhibition is considered to be distinct from interference suppression because an individual has to resist executing a habitual response, instead of avoiding being misled by distraction (Bunge et al., 2002). Therefore, it is the specific ability of selecting the correct response while managing conflict, involuntarily triggered by irrelevant information, that bilinguals are believed to be superior in relative to monolinguals (Bialystok et al., 2008; Martin-Rhee & Bialystok, 2008). In the following sections, the background of the two forms of inhibition relevant for the present experiment is detailed.

In tests of interference suppression, researchers often employ tasks that present a series of stimuli which contain congruent and incongruent features. Congruent trials contain stimuli that are easily interpreted and can be directly mapped to a response. Incongruent trials on the other hand contain misleading information which must be suppressed before a correct response can be selected. As a result of having to shift away from misleading information, and then having to suppress it, incongruent trials take longer to perform than congruent trials. The delay is believed to be caused by the extra time needed to overcome the perceptual interference presented by incongruent information (Bialystok et al., 2004). The efficiency of interference suppression is calculated as the time cost it takes to perform an incongruent trial compared with a congruent one (Bialystok et al., 2008; Martin-Rhee & Bialystok, 2008). The interference effect has been investigated using a variety of tasks, most notably the Simon task and the flanker task (Figure 12).

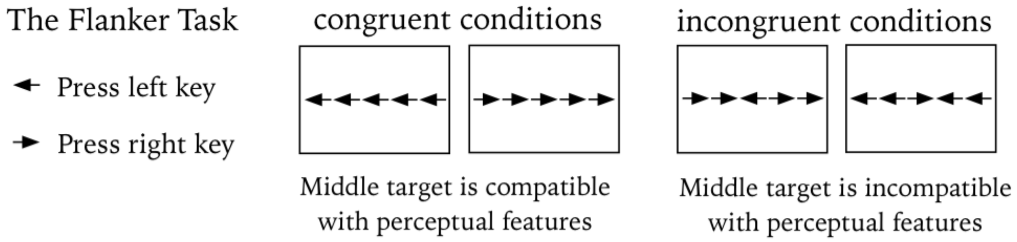


Figure 12: The flanker task. Participants have to respond to the target middle arrow.

Response inhibition refers to the cognitive ability to withhold an intended act (Aron et al., 2004). Tasks testing for it do not typically contain conflicting features. Instead, participants have two response options, one of which is more habitual, and therefore more strongly associated with a particular response, than the other option. Successful performance rests on overriding this tendency to respond in a particular way, rather than overriding perceptual distraction caused by conflicting stimuli. For example, in studies investigating response inhibition, participants completing a computer-based task may be instructed to respond with a keypress whenever an English letter appears on the screen, but have to withhold their responses if the letter is an “X” (Casey et al., 1997; Menon, Adleman, White, Glover, & Reiss, 2001). Response inhibition is successfully executed when participants manage to withhold pressing the key to stop responding only on trials showing “X”.

By contrasting interference suppression with response inhibition, researchers have been able to highlight that bilinguals are, in particular, superior in interference suppression due to the honing of this skill in bilingual discourse. Results however, have been mixed.

Bialystok et al. (2008a) tested monolingual and bilingual older adults in a task where the participants had to indicate the direction of an arrow in the centre of a screen. This was the first condition. In the second (response inhibition) condition, the arrow appeared… …arrow. In the third (interference suppression) condition, the arrow appeared on either the left or right side of the screen. To prediction, bilinguals outperformed monolinguals in the third, but not the second or first condition. Unexpectedly however, young adult bilinguals who were tested with the same task did not show any advantage. Martin-Rhee and Bialystok (2008) ran the same task on monolingual and bilingual children. They demonstrated a bilingual advantage, but this was related to faster RT shown by bilingual children in the first condition (i.e. no conflict).

If the dissociation between interference suppression and response inhibition in bilingual behaviour is the basis for the claim that being bilingual positively influences the executive control of interference and not just any form of control, then the above pattern of results do not support this claim. Bialystok (2001) offers a plausible reason for why the advantage in interference suppression has been inconsistent in groups other than older adults. She asserts that bilinguals solve tasks better than monolinguals when the tasks are high in their demand for control. This is supported by two studies. Bialystok et al. (2004) found that by increasing the difficulty in the Simon task, the bilingual advantage in interference suppression in young adults was more pronounced than if this group was tested with the standard Simon task. Martin-Rhee and Bialystok (2008) similarly reported a better performance in bilingual children in the more difficult Simon task conditions than the easier ones.

Therefore, given the above issues of generality of the bilingual advantage, as well as the usefulness of testing for interference suppression against response inhibition, the present study examined the bilingual advantage in young adult monolinguals (n = 12) and balanced bilinguals (n = 12) via a modified flanker task. This task was modified to be sufficiently challenging for the young adults. It was predicted that if the bilingual experience of constantly suppressing competing words from two languages enhanced their interference suppression ability, then balanced bilinguals would show an advantage over matched monolinguals on trials that tested for interference suppression but not on those that tested for response inhibition.

To this end, a task was required that tested the participants on abilities of interference suppression and response inhibition. Stimuli had to contain both compatible and incompatible perceptual features to targets, as well as cues that signalled for the cancellation of response tendencies. The task also needed to be sufficiently demanding to avoid ceiling effects that might obscure differences between groups, especially of college-aged students who were at their developmental peak (Bialystok et al., 2005). Following Bialystok et al. (2004), the task used here was modified to have a demanding condition, and also retained a less demanding condition to provide an index of the two abilities as conventionally measured by researchers (e.g., Bunge et al., 2002). That is, for each ability, there would be one measure that reflected processing under low task demands, and another measure that reflected processing under high task demands. The task used in this study was based on the flanker task used by Bunge et al. (2002) (Figure 13).

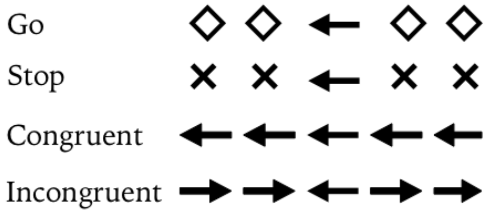


Figure 13: The flanker task used by Bunge et al. (2002), showing left-pointing targets. Right-pointing targets are not pictured above. Participants indicated with a left or right key the direction of the target. In the Stop condition, no response was to be made. Congruent trials were contrasted with Incongruent trials to assess interference suppression effects; the number of withheld responses on Stop trials was expressed as a proportion of no-go trials to assess response inhibition effects. Bunge et al. (2002) carried out all four conditions in a single mixed block with each condition occurring with equal frequency.

Method

Participants

24 undergraduates from the National University of Singapore received modular credit or monetary payment for their participation. They gave informed consent and approval for the

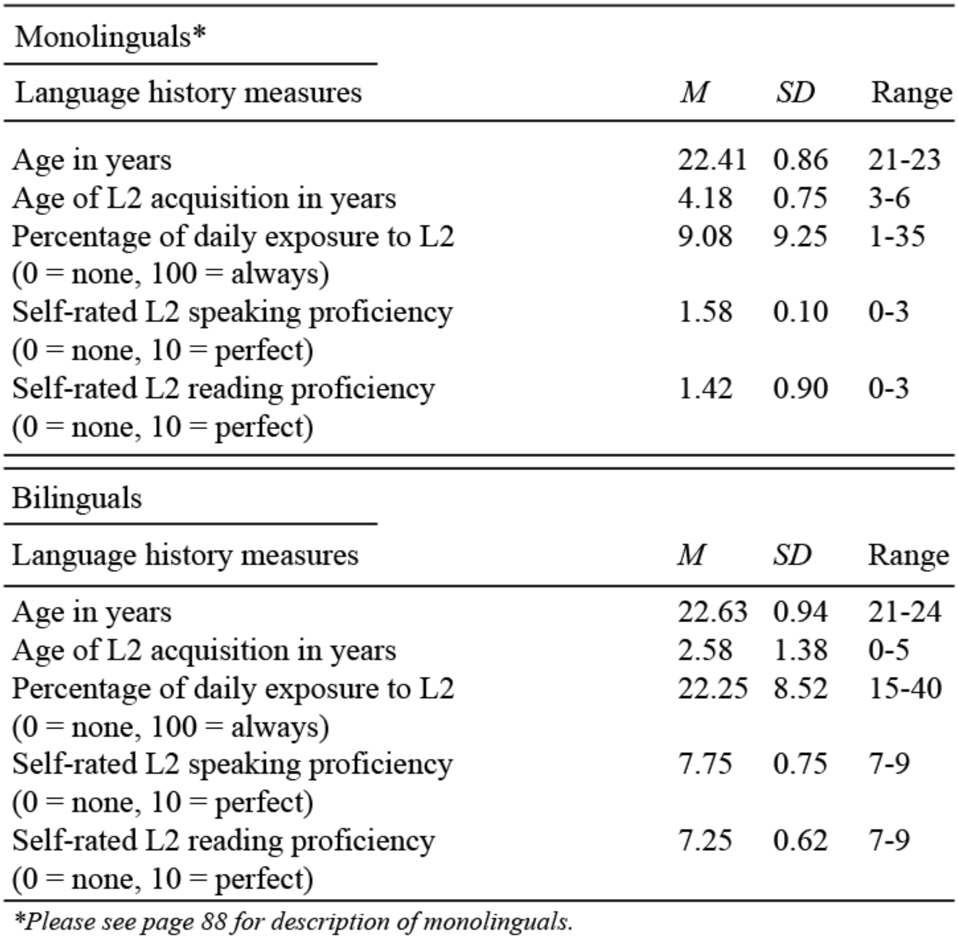
study protocol was obtained from the local institutional ethics commitee. All participants were administered the Language Experience and Proficiency Questionnaire (LEAP-Q) (Appendix A) developed by Marian, Blumenfeld, and Kaushanskaya (2007). This questionnaire is able to document the language profiles of bilinguals from diverse linguistic and cultural backgrounds. Participants were grouped according to self-reports of monolingualism or bilingualism. This method worked for classifying monolinguals. However, for categorising bilinguals, the LEAP-Q does not provide a coding system to assess L1 or L2 proficiency. For this, we followed Kaushanskaya and Marian's (2009) method of assessing high L2 proficiency via the LEAP-Q which focused on four history variables. These were the age at which L2 learning began, the percentage of daily exposure to L2, and self-rated L2 speaking proficiency, and self-rated L2 reading proficiency. The high proficiency bilinguals in Kaushanskaya and Marian's study were a mean age of 5 years when they began acquiring L2, were exposed to L2 daily for a mean of 12%, and on average rated their speaking and reading proficiency as 7 out of 10. Therefore, we took these values as the cut-off ratings for high-proficiency bilinguals. Bilinguals who classified themselves as balanced, and who met these cut-offs, were included in the study. Participant details are provided in Appendix E.

Monolingual participants (n = 12, mean age = 22.41, *SD* = 0.86, age range = 21-23) reported speaking only English, although they were exposed to another language (Mandarin, Malay, or Tamil). All monolingual participants began learning English as an infant and spoke only English in all communicative instances. They understood greetings in the foreign language but were not functionally fluent in this language.

Bilingual participants (n = 12, mean age = 22.63, *SD* = 0.94, age range = 21-24) reported speaking only in both English and their second language. The non-English language spoken by the participants were Mandarin (n = 9), Malay (n = 2), and Cantonese (n = 1).

Tables 2a and 2b

The language history and proficiency characteristics of monolinguals (table 2a, top) and bilinguals (table 2b, bottom) in Experiment 1 (see Appendix E).



Monolinguals*

Language history measures	*M*	*SD*	Range
Age in years	22.41	0.86	21-23
Age of L2 acquisition in years	4.18	0.75	3-6
Percentage of daily exposure to L2 (0 = none, 100 = always)	9.08	9.25	1-35
Self-rated L2 speaking proficiency (0 = none, 10 = perfect)	1.58	0.10	0-3
Self-rated L2 reading proficiency (0 = none, 10 = perfect)	1.42	0.90	0-3

Bilinguals

Language history measures	*M*	*SD*	Range
Age in years	22.63	0.94	21-24
Age of L2 acquisition in years	2.58	1.38	0-5
Percentage of daily exposure to L2 (0 = none, 100 = always)	22.25	8.52	15-40
Self-rated L2 speaking proficiency (0 = none, 10 = perfect)	7.75	0.75	7-9
Self-rated L2 reading proficiency (0 = none, 10 = perfect)	7.25	0.62	7-9

**Please see page 88 for description of monolinguals.*

Apparatus

The experiment was held in a soundproof booth running on a 2.83 GHz duo core processor PC coupled to a 14.5 × 12 inch LCD colour monitor. Stimuli presentation and reaction time measurement were controlled by Presentation® software (Version 16.3, www.neurobs.com). The participant sat at 0.5m from the screen.

Stimuli

There were six conditions in the modified arrows task (Figure 14). Middle target arrows were in green or red. Participants had to respond in the same direction of the target if it was green (Same condition), but in the reverse direction if it was red (Reverse condition). Each target appeared in the centre of the screen accompanied by four identical distractor arrows (flankers). In all, there were six conditions: Stop, Control, Same Congruent, Same Incongruent, Reverse Congruent, and Reverse Incongruent. *Same* and *Reverse* informed participants of the response to be made in relation to the direction of the target, and *Congruent* and *Incongruent* indicated the direction of the flankers relative to the target. All flankers were in black and equally distributed to the target's left and right horizontal.

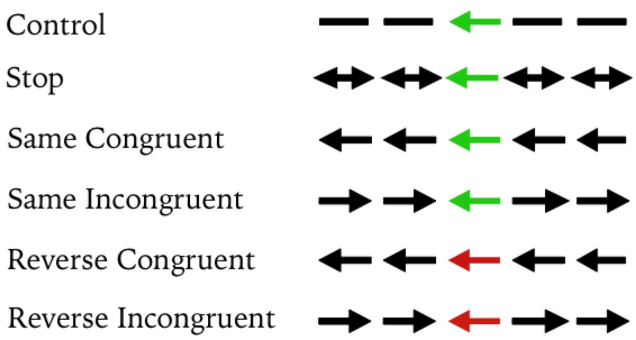


Figure 14: The six conditions of the modified arrows task, showing left-pointing targets. Right-pointing targets are not pictured above. Participants had to indicate the direction of the target except in the Stop condition where they had to withhold their response.

Figures 13 and 14 show that the first four conditions in our modified task are analogous to the conditions used by Bunge et al. (2002). To fulfil the criteria of increasing task demands, the Reverse Incongruent condition supplied an additional interference suppression condition and the Reverse Congruent condition supplied an additional response inhibition condition. Given that young adults have been reported to be highly accurate (95.5%) on being able to stop their responses (Bunge et al., 2002), these additions had the ideal outcome of increasing the total number of trials which made the Stop condition more difficult, and which would increase the optimization of response inhibition processes.

For a trial to tap into interference suppression abilities, there had to be a source of perceptual conflict that participants had to overcome. In Figure 14, these were the incongruent conditions where flankers and targets were in opposing directions. The measure of interference suppression was the difference in time taken to complete Incongruent trials versus Congruent trials. This yielded two measures of interference suppression ability. One in the Same condition reflecting the use of interference suppression under low task demands, and one in the Reverse condition reflecting the use of interference suppression under high task demands. Compared with the Same condition, in the Reverse condition, participants had to additionally ignore the direction of the target. This made the Reverse condition more difficult.

Tapping into response inhibition processes requires inducing in participants the stopping of their tendency to respond. Two qualities set response inhibition trials apart from interference suppression trials. First, it is generally agreed that prior to cuing participants to stop their response, they should already be biased in a state of ongoing response (Garavan, Ross, Murphy, Roche, & Stein, 2002). Second, the suppressing of a response is conveyed by a cue, rather than a salient conflict. In our experiment, this was achieved by having a low probability of Stop trials. Red arrows in the Reverse conditions and bi-directional arrows in the Stop condition served as cues. In the Reverse conditions, participants had to resist the impulse to respond in the direction of the target. In the Stop condition, participants had to shift their attention to the flankers, ignore the signal associated with a green target, and halt their response. Even though participants have to ignore distractors in the Reverse condition, given that the condition nevertheless entails the executing of a keypress response which accounts for 83.3% of all trials, versus 16.7% of all trials which require the complete withholding of any response, the Stop task was the more difficult of the two conditions. To measure response inhibition under low task demands, the time taken to respond to Same Congruent conditions was subtracted from that of Reverse Congruent conditions. To measure response inhibition under high task demands, the percentage of correctly withheld responses in the Stop condition as a proportion of all correctly withheld responses in other conditions was totalled.

In sum, each picture stimulus was composed of a target and four identical flankers that were distributed equally on the left and right sides of the target. The target pointed in one of two directions (left or right) in one of two colours (red or green). Black coloured flankers appeared in one of four shapes (left arrow, right arrow, bi-directional arrow, or a line). Stimuli were drawn with lines 14 mm wide, horizontally aligned, and spaced 3 mm apart.

Each block consisted of 48 trials, a third of which were equally occurring Stop and Control trials and the remaining two-thirds were divided between congruent (Same +

Reverse) and incongruent (Same + Reverse) trials. In the Congruent and Incongruent conditions, there were equal numbers of left- and right-pointing red and green targets. Equal numbers of left- and right-pointing targets (except they were all green) also occurred in the Stop and Control conditions.

Procedure

Participants were instructed that all flankers were irrelevant except for the Stop condition and were to concentrate on responding to the target as fast as they could. If the target was green, the subject was instructed to press a key corresponding to its direction. If the target was red, the subject needed to press a key in its opposite direction. If however the target appeared with bi-directional flankers (←→), they were to refrain from responding at all.

Each trial began with a fixation cross on a white screen and was replaced with the stimulus after 1,000 ms. A maximum response time of 2,000 ms was allowed after which a blank screen appeared for 1,000 ms before the next trial commenced. Stimuli sequences were pseudo-randomly generated such that there were 8 Stop trials, 8 Control trials, 16 Same trials, and 16 Reverse trials in each block of 48 trials. Each subject worked through 6 such blocks. Prior to the session, participants familiarised themselves with the experiment by running through two practice blocks that were separately generated from the experimental block sequence; practice blocks were the same for every participant.

Data Analysis and Results

Analyses on errors made were first conducted. Participants' mean percentage errors ranged from 0% to 0.1% in the two Same conditions and 0% to 0.17% in the two Reverse conditions. These errors were excluded from RT analyses. No outliers were detected (Figure 15). A mixed three-way ANOVA for language group (monolingual, bilingual), target direction (Same, Reverse) and flanker direction (congruent, incongruent) showed that more errors were made when the target was reversed than when it was not, F (1, 22) = 25.20, $p <$ .0001, and when flankers were incongruent than when they were congruent, F (1, 22) = 1.18,

$p < .023$. No group differences were detected, F (1, 22) = .03, $p = .875$, and there were no significant interactions.

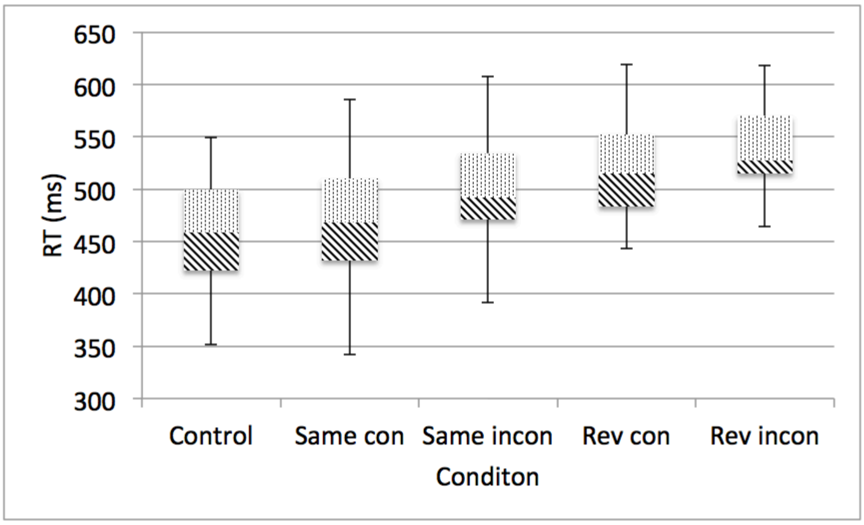


Figure 15: Box and whiskers plot indicated the mean percentage errors approximated to Normal distributions and no outliers were detected.

The mean of median reaction times (RT) by trial type and language group are shown in Figure 16 on the next page. Participants' median response times were submitted to a mixed three-way ANOVA with the factors language group (monolingual, bilingual), target direction (Same, Reverse) and flanker direction (congruent, incongruent). This showed main effects of target direction, F (1, 22) = 50.73, $p < .0001$, and flanker direction, F (1, 22) = 35.28, $p < .0001$, but there was no difference between the language groups, and no flanker direction by language group interaction (all *p*s > .05). This showed that the Same condition was easier than the Reverse condition, and that the Congruent condition was easier than the Incongruent condition.

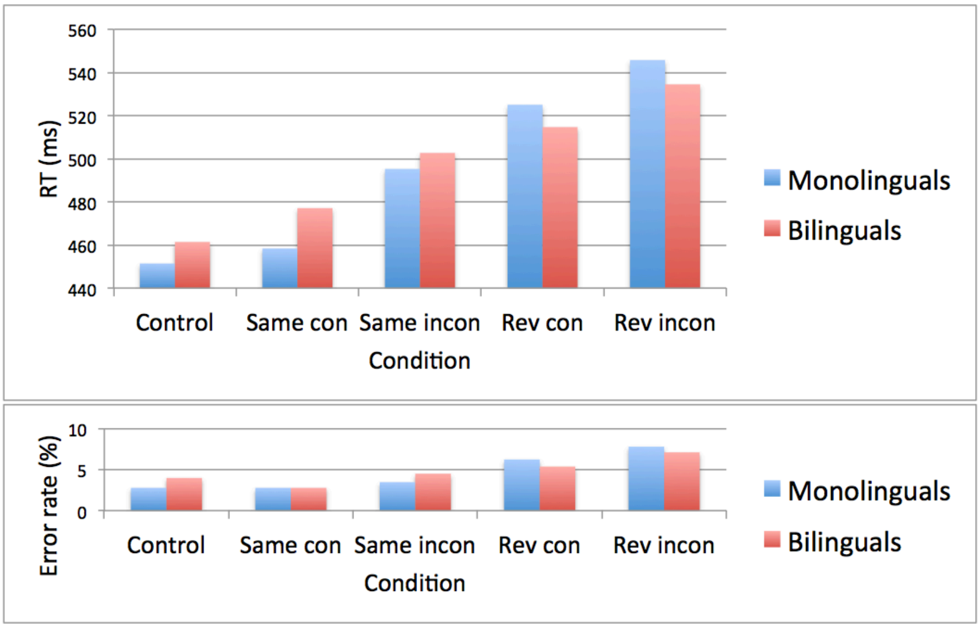


Figure 16: The mean of median reaction time of monolingual and bilingual participants plotted across five conditions. The forms "con" and "incon" represent "congruent" and "incongruent" respectively; "Rev" represents "Reverse" (the Stop condition is in percentage and not shown on the graph).

Figure 16 showed that monolinguals were faster than bilinguals in the Control and Same Congruent condition. The RT for these two conditions were submitted to a mixed two-way ANOVA with the factors language group (monolingual, bilingual) and flanker presence (present, absent). There was a main effect of flanker presence, F (1, 22) = 5.71, $p < .026$, but no significant group differences, F (1, 22) = .85, $p = .365$.

We next considered the RT in terms of the interference suppression effect. Following the approach of Bialystok et al. (2008) and Martin-Rhee and Bialystok (2008), the interference suppression effect was defined as the difference in RT between congruent and incongruent trials. The numerical differences between groups are first reported. Table 3 below shows that the interference effect experienced by bilinguals in the Same condition (503 – 477 = 26 ms) was smaller than that experienced by monolinguals (495 – 458 = 37 ms). In the Reverse condition, there were no differences between them (bilinguals: 534 – 513 = 21 ms; monolinguals: 546 – 525 = 21 ms). The mixed 2 × 2 ANOVA on these RTs for the factors language group (monolingual, bilingual) and task demand (high, low) did not show any significant differences between groups, F (1, 22) = .76, $p < .391$, demonstrating that bilinguals had no advantage over monolinguals in terms of interference suppression, in both the Same and Reverse conditions.

Table 3
Mean of median (M) reaction time in milliseconds (ms) and error rates for each condition by language group.

		Monolinguals			Bilinguals		
Condition		*M* (ms)	*SD*	Error (%)	*M* (ms)	*SD*	Error (%)
Stop		-	-	23	-	-	17
Control		451	56	2.77	461	54	3.99
Same	Congruent	458	59	2.77	477	65	2.77
	Incongruent	495	57	3.47	503	52	4.51
Reverse	Congruent	525	51	6.25	513	44	5.38
	Incongruent	546	43	7.81	534	38	7.12

As with the interference suppression conditions, the data for response inhibition conditions were examined. The first index of response inhibition was the difference in response times between the Same Congruent trials and Reverse Congruent trials, and the second index of response inhibition was the number of correct withheld responses as a percentage of the total number of responses to be withheld. Table 3 showed that when the target was reversed, bilinguals were quicker to react (513 – 477 = 36 ms) than monolinguals (525 – 458 = 67 ms). Bilinguals also made fewer errors (23%) than monolinguals (17%) in the Stop condition. A two-tailed t-test showed marginal group differences in responding to a reversed target, *t* (22) = 1.989, *p* = .059, and none in withholding a response, *t* (22) = .842, *p* = .409.

Discussion

Experiment 1 attempted to replicate the bilingual advantage in tasks of interference suppression in young adult bilinguals. As a basis for comparison, response inhibition ability was tested as a form of inhibition distinct from interference suppression. The prediction according to theory was that a bilingual advantage over monolinguals would be seen in interference suppression, and not response inhibition (Bialystok et al., 2004; Green, 1998).

The results are clear. There were no significant differences between monolinguals and bilinguals on all trials. Incongruent trials were more difficult than congruent trials for both groups, as were the Reverse conditions compared with the Same conditions. Error rates increased as RT increased and therefore ruled out any speed-accuracy trade-offs. Data analysis showed that bilinguals did not appear to enjoy any form of advantage over monolinguals, under any specific condition. The results of this experiment joins previous studies that have failed to find a reliable bilingual advantage in interference suppression in young adults (Bialystok et al., 2004; Paap & Greenberg, 2013).

We however did find a numerical lead that bilinguals had over monolinguals, and that Bialystok et al. (2008) observe to be "consistently replicable" (p. 868). Bilinguals experienced less interference under the Same condition, were quicker to respond to a reversed target, and made fewer mistakes under the Stop condition. Although the magnitude of numerical differences obtained in this study are consistent with that reported in other studies (Bialystok et al., 2008; Martin-Rhee & Bialystok, 2008), there were no effects of group differences and the implication of such an outcome must be considered.

The two main assumptions made in view of the bilingual advantage is that firstly, fluent speech is achieved through the suppression of unneeded words (Green, 1998). Secondly, since bilinguals constantly manage two languages, by extension of the first assumption, they must have twice the experience at applying this skill in their verbal environment compared to monolinguals, and therefore must be superior at interference suppression (Bialystok et al., 2004). Our results suggest that suppression may not be involved in bilingual language production, or that if it is, other factors may be involved such that the benefits gained from constantly suppressing a language may not extend to the non-language domain. The overwhelming evidence demonstrating the involvement of suppression in bilingual language production (Costa & Santesteban, 2004; Jackson et al., 2001; Meuter & Allport, 1999; Philipp et al., 2007) leads us to consider the second possibility that bilinguals may enjoy an interference suppression advantage that is confined to the language domain. Since this transference of skills from the language to non-language domain had not yet been examined despite the numerous studies built on its working assumption (e.g., Bialystok, Martin, & Viswanathan, 2005; Martin-Rhee & Bialystok, 2008), we addressed this untested assumption in Experiment 2.

CHAPTER 6 – EXPERIMENT 2

Overview

Experiment 1 had failed to find a bilingual advantage in interference suppression. This questions the claim that bilinguals are better than monolinguals at suppressing non-language interference because of having had more practice at suppressing language interference in daily bilingual communication. Researchers point out that bilingual lexical selection may not proceed from suppression (Costa et al., 1999), much less suppression of a particular kind (Finkbeiner et al., 2006). La Heij (2005) argues that activation levels and unique word features are sufficient to guide lexical selection while Costa (2005) believes that suppression processes can only be inferred and not directly measured. In all, these researchers imply that language selection may take place through means other than suppression and that earlier reports of the bilingual advantage may not be completely attributable to suppressing lexical interference. This is in line with research that has shown that interference suppression skill may be enhanced by experiences (e.g., playing video games) other than bilingualism (Bialystok, 2006).

Experiment 2 was interested in this issue. If it could be demonstrated that bilinguals have an advantage over monolinguals in tasks that test for language interference suppression, then the basis for extending the IC model into the bilingual advantage hypothesis is viable, and the null result of Experiment 1 must be re-examined. However, the comparison of monolinguals and bilinguals at suppressing language interference has not been explored. For this, we based our task on the picture-word interference (PWI) task since it is a primary tool for probing the ability to suppress language units.

In the PWI task, participants are asked to name a picture while attempting to ignore a distractor word which may or may not be related to the picture. PWI naming latencies therefore offer insight into a speaker's ability to rapidly access the lexicon, select the correct representation, and execute a verbal response, all the while being confronted with a potentially interfering word. The influence of distractors on picture-naming is experienced by language speakers (Glaser & Dungelhoff, 1989; Starreveld & La Heij, 1995), including bilinguals (Caramazza & Costa, 2000; Costa et al., 2000; Hermans et al., 1998), indicating that monolinguals and bilinguals both require, and possess, a mechanism that suppresses unwanted words. Since the PWI task taps into the lexical selection mechanism in both these groups, it is possible to compare language interference suppression ability between them.

Doubts about its suitability may be raised on the grounds that monolinguals and bilinguals are handling different linguistic loads during performance. If bilinguals are dealing with twice the number of activated lexical representations than monolinguals, then it is natural to assume that they will be at a disadvantage in the PWI task. This would be a concern if task material used were bilingual. Research probing the interference of the non-target language on the target language have necessarily had to use material in two languages (e.g., using a second language (L2) distractor during first language (L1) response). This would have inadvertantly activated the irrelevant language to a certain degree. Elston-Guttler, Gunter, and Kotz (2005) showed that when bilinguals were exposed to L2-only material, they did not experience L1 interference when making decisions on cognates that were embedded in L2 sentences. In this study, participants were exposed to their less dominant language. If bilinguals are primed in their weaker language and do not suffer from L1 interference, it is plausible that bilinguals immersed in a context where only their dominant language is used will be minimally influenced by L2, if at all. In the current experiment, only the participants' L1, English, was used.

In parallel with our efforts to investigate both interference suppression and response inhibition in the language domain, the PWI task which poses only language interference, is inadequate for this purpose. Therefore, Experiment 2 built a response inhibition component into the PWI task. Two procedures were introduced. These were to (1) require participants to alternate between naming the picture and reading the distractor (2) use a set of go and no-go cues to indicate the relevance or irrelevance of each task on each trial. As in Experiment 1, steps were taken to manipulate task demands. This was done by varying the time available on each trial. Task construction is detailed in the Method section.

24 university students who had not participated in the prior experiment were recruited for the current experiment.

If bilinguals showed an advantage in language interference suppression but none for language response inhibition then it may be argued that enhanced interference suppression control seen in bilinguals relates to their experience of having to inhibit the irrelevant language.

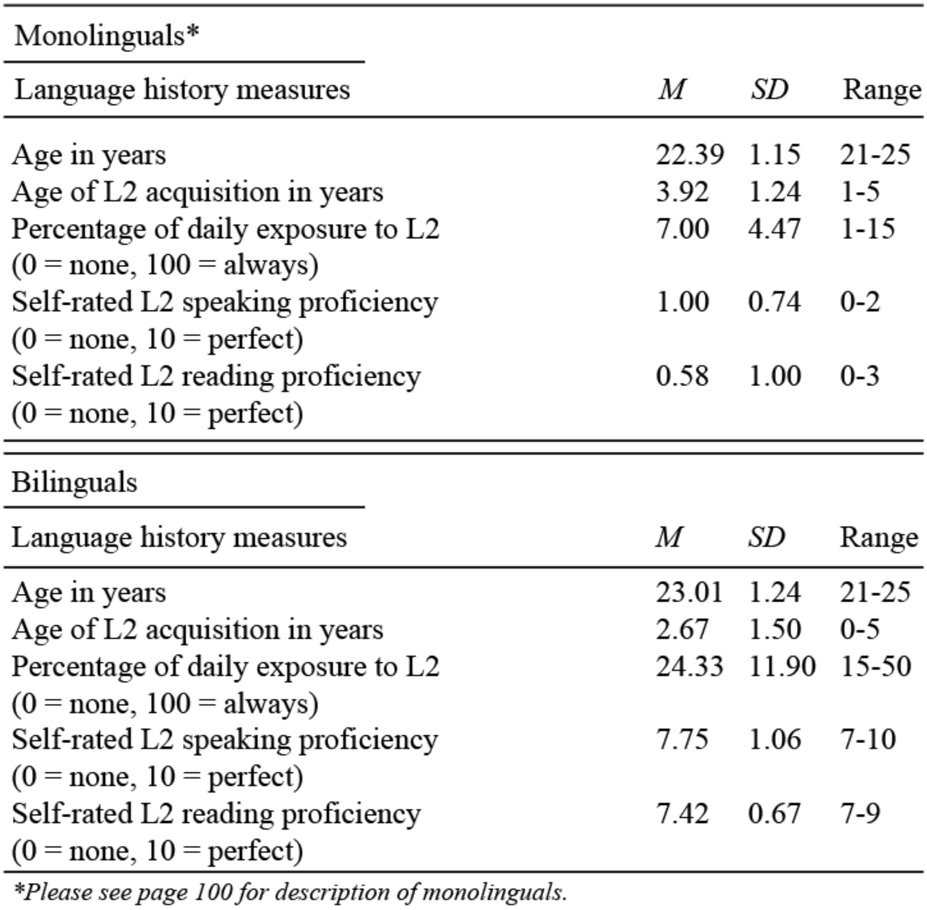
Method

Participants

24 undergraduates from the National University of Singapore received modular credit or monetary payment for their participation. They gave informed consent and approval for the study protocol was obtained from the local institutional ethics commitee. They were divided into a monolingual group (n = 12, mean age = 22.39, *SD* = 1.15, range = 21-25) and a bilingual group (n = 12, mean age = 23.01, *SD* = 1.24, range = 21-23). Monolinguals reported using English all their lives and were exposed to Mandarin, Malay, and Tamil although they didn't speak it. Three monolinguals reported being able to order a few dishes in Mandarin but did not use Mandarin in other contexts. All monolinguals came from English-speaking families. Bilingualism was established with the LEAP-Q (Marian et al., 2007) and followed the same procedures in Experiment 1. As a comparison, monolinguals were instructed to provide information on the variables which applied to them.

Tables 4a and 4b

The language history and proficiency characteristics of the monolingual (table 4a, top) and bilingual (table 4b, bottom) group in Experiment 2 (see Appendix E).



Monolinguals*

Language history measures	*M*	*SD*	Range
Age in years	22.39	1.15	21-25
Age of L2 acquisition in years	3.92	1.24	1-5
Percentage of daily exposure to L2 (0 = none, 100 = always)	7.00	4.47	1-15
Self-rated L2 speaking proficiency (0 = none, 10 = perfect)	1.00	0.74	0-2
Self-rated L2 reading proficiency (0 = none, 10 = perfect)	0.58	1.00	0-3

Bilinguals

Language history measures	*M*	*SD*	Range
Age in years	23.01	1.24	21-25
Age of L2 acquisition in years	2.67	1.50	0-5
Percentage of daily exposure to L2 (0 = none, 100 = always)	24.33	11.90	15-50
Self-rated L2 speaking proficiency (0 = none, 10 = perfect)	7.75	1.06	7-10
Self-rated L2 reading proficiency (0 = none, 10 = perfect)	7.42	0.67	7-9

**Please see page 100 for description of monolinguals.*

Apparatus

The experiment was held in a soundproof booth running on a 2.83 GHz duo core processor PC coupled to a 14.5 × 12 inch LCD colour monitor. Audio responses were captured by an Audio Technica microphone and a primary sound driver. Stimuli presentation and reaction time (RT) measurement were controlled by Presentation® software (Version 16.3, www.neurobs.com). The participant sat at 0.5 m from the screen and 3 cm away from the microphone.

Stimuli

To study language interference, a language context must be created where two semantic concepts race for verbal production but only one response is accepted thereby forcing one other response to be suppressed. The PWI task achieves this by superimposing a semantically related distractor to a picture which results in delayed picture-naming latencies compared with when the distractor is unrelated (e.g., Starreveld & La Heij, 1995).

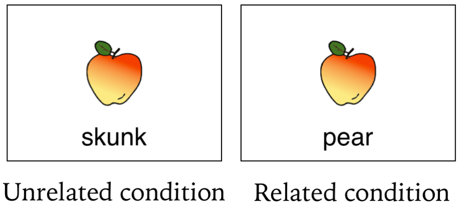


Figure 17: Sample stimulus of apple for the picture-word interference task. Participants name a picture that is accompanied by a semantically unrelated distractor (left) or a semantically related distractor (right). The semantic interference effect refers to the longer time needed to name a picture when the distractor is semantically related than when it is semantically unrelated.

Traditional testing of response inhibition is done through the go/no-go task (Verbruggen & Logan, 2008). In this task, participants must react quickly to a set of *go* stimuli and withhold responses to another set of *no-go* stimuli. Typically, the number of go trials outnumber no-go trials to induce in participants a default state of being response-ready, so that response inhibition processes are optimized on no-go trials. In developing a response inhibition component to the PWI task, we needed a set of no-go trials to which participants had to withhold verbal responses biased to go trials.

Colour coded letter cues preceding the picture-word stimulus to convey go and no-go signals were introduced. A green go cue *N* signalled to participants to *name the picture* and a red no-go cue *N*, *do not name the picture*; the time before the stimulus appeared allowed participants to process these cues (Figure 18). This use of cues fulfilled the criteria of having two sets of stimuli that differentiated between verbal responses biased to a set of stimuli and withheld to another set.

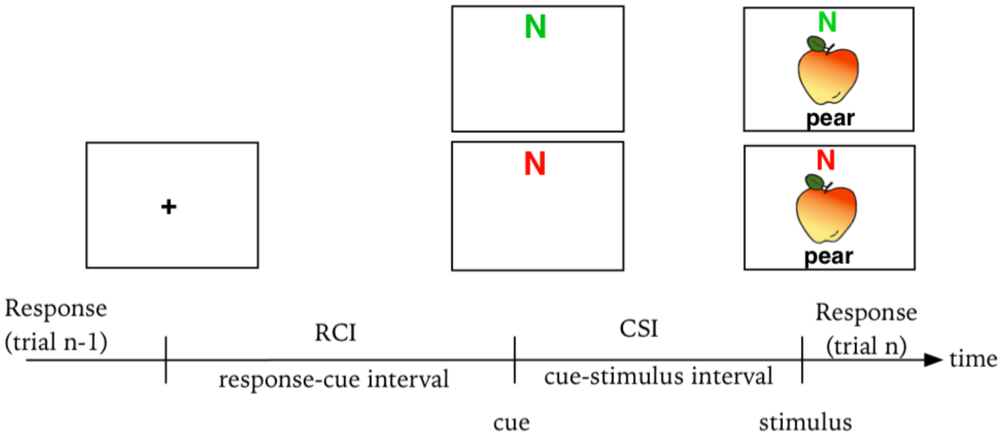


Figure 18: The cued picture-word interference task showing stimuli with related distractors. Using a cue allowed control over whether the following trial should be suppressed or not. A congruent trial (green N) measured picture-naming and an incongruent trial (red N) measured response inhibition. The response-cue interval (RCI) represents the resting time from the last response to the cue and the cue-stimulus interval (CSI) allows cue-processing to take place before the onset of the stimulus.

A problem with this design is that even if a cue signalled for a stop in picture-naming, there was no guarantee that participants were driven to respond (a prerequisite state of behaviour for response inhibition processes to be exercised). This is because if participants knew in advance (through the cue) that no response was needed on the following trial, they could choose to terminate incomplete lexical access processes prior to naming, and before the onset of the stimulus. In typical studies of response inhibition, researchers use tasks that draw on rapid, reflexive motor urges such as the human eye gaze (e.g., Bialystok, Craik, & Ryan, 2006). Word retrieval is of a higher order process. It calls for the complex mapping of a stimulus to a specific verbal response that involves searching the lexicon, matching stimulus features to stored representations, and assembling a verbal output (Green, 1998; La Heij, 2005). This implies that the picture-naming task could be abandoned based on the effort it takes to retrieve a word, and not on the difficulty of suppressing an involuntarily retrieved word.

To solve this, on no-go trials, participants were required to perform a separate verbal task, as soon as the present verbal task was suppressed. This meant that participants switched between two verbal tasks of which only one was relevant at a time. For any verbal task that was cued to be suppressed, the correct response was to perform the *other* verbal task. Since a response was required on every trial and the success of suppressing a task was salient, participants were encouraged to remain on-task and response-ready. This way, a response either measured the time taken to perform the verbal task that was cued (on go trials), or it collectively measured the time taken to suppress one verbal task, and perform the other (on no-go trials). The measure of response inhibition then was taken as the difference between go trials and no-go trials. The equivalent of no-go trials in the present experiment are *incongruent* trials.

This solution was implemented by including distractors as part of target stimuli for a reading task. Green *R* and red *R* cues were introduced into the existing task. On congruent trials, green cues informed participants to proceed with the assigned task. On incongruent trials, red cues informed participants to withhold performing the task associated with the letter, and to proceed carrying out the other task. That is, if the naming task was irrelevant, the distractor had to be read; if the reading task was irrelevant, the picture had to be named. Cues were presented in uppercase Arial font with a height of 2 cm and displayed in the upper vertical axis 3 cm off the screen centre.

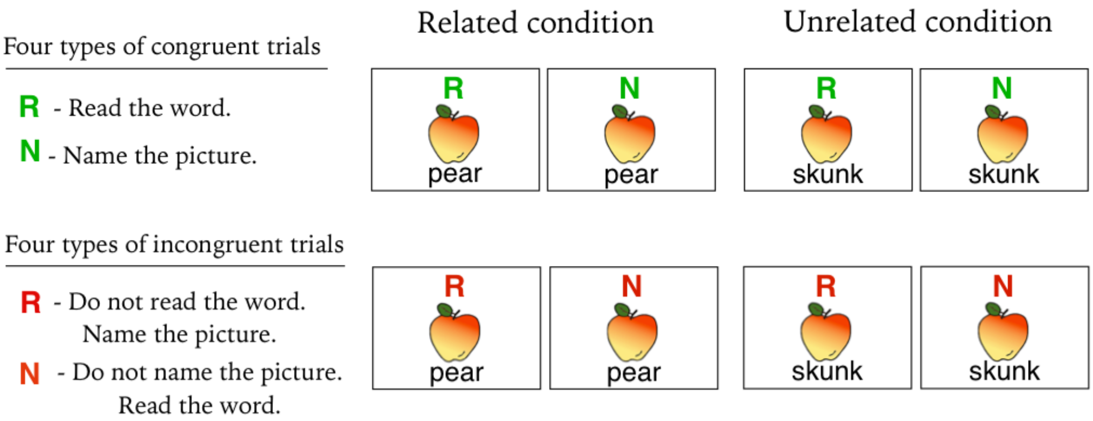


Figure 19: Sample stimuli in the cued picture-word interference task showing the combinations possible with the picture stimulus apple. Semantic relatedness of distractors and cue congruency were manipuated to achieve eight possible outcomes. In the experiment, pictures were not repeated within a block. Related conditions tested for language interference suppression and incongruent conditions tested for language response inhibition.

The CSI was varied to manipulate task difficulty. Evidence shows that participants find task conditions challenging when the CSI is shorter than when it is longer (Monsell & Mizon, 2006). This is because once the cue appears, participants are able to actively use the

CSI and direct efforts to the new task; a short CSI deprives participants of the opportunity to prepare adequately for an upcoming task. With the possibility that a bilingual advantage may only be demonstrated under difficult situations (as argued in Experiment 1), the experiment varied the CSI with a short interval and a long interval to create a difficult condition (short CSI) and an easy condition (long CSI). CSI values were based on the work of Monsell and Mizon whose research has established the influence of this variable.

A consequence to introducing a CSI is that a RCI is created and possible confounds associated with it must be considered. Research has shown that when participants complete a trial, there is residual trial activity that is carried over to the next trial in the RCI (Meiran et al., 2000). This carryover activation of the previous trial is believed to decay over the RCI (Allport et al., 1994). In the present experiment, if the RCI is too long, participants may not sustain their language settings that were biased to a particular response (to complete no-go trials optimally). And yet, if the RCI is too short, carryover activation may disrupt the processing of the cue for the next task. It is noted however that RCI effects on performance, if present, are minimal (Horoufchin, Philipp, & Koch, 2011; Meiran et al., 2000). Nevertheless, without prior literature on the effects of RCI on verbal performance, we took the precaution of incorporating a long and short RCI into the experiment with the intention of averaging performance across these conditions if they were not found to significantly affect reaction time.

260 picture stimuli from the validated Snodgrass and Vanderwart (1980) set were used (Appendix B). Their suitability was based on several standardized variables which included their most common name in English, picture familiarity, picture complexity, and the picture-mental representation agreement. All pictures were framed by a white-filled rectangle measuring 6 cm by 10 cm. Participants sat 50 cm from the screen which was placed at eye level.

Each picture was displayed in the screen centre and the distractor vertically aligned below it. Semantically related and unrelated words were generated on the basis of categorical class, phonological similarity, frequency, and length. A word (e.g. “cat”) was considered to be related to the picture if it belonged to the same category of objects as did the picture (e.g. "dog"). No related word was a composite (e.g. "tail") of its picture to prevent possible naming facilitation effects (Costa, Alario, & Caramazza, 2005). The categories used in the experiment were animals, insects, vehicles, plants, clothes, furniture, household objects, and food. Phonologically similar picture-word pairs were avoided so that there was no sharing of consonantal phonemes in the onset, or the vowel phoneme following the onset, or a combination of both. Word length did not exceed four syllables. 93% of words that appeared as a related word to a picture, also appeared as an unrelated word with a different picture. Frequencies were provided by the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). Each word was presented in lowercase in Times New Roman font size that reached 1 cm in height and was displayed 3 cm off the centre (Appendix C).

The language interference suppression effect was operationalised as the difference in time taken to complete related congruent trials compared with unrelated congruent trials. The language response inhibition effect was operationalised as the difference in the time taken to complete unrelated incongruent trials compared with unrelated congruent trials.

Procedure

Prior to the experimental session, participants carried out a rapid picture-naming test in English as a baseline measure for lexical retrieval speed. They were instructed to name as quickly as they could, and to avoid categorical names (e.g., avoid "fruit" for apple). The test consisted of 2 blocks of 64 trials each with stimuli used from the same experimental pool of pictures. The same order of stimuli and order of blocks were repeated across participants. The test began with a fixation cross that appeared in the screen centre for 1,000 ms before a picture appeared. A given response terminated the picture and the next trial began after 500 ms. Participants practiced with 2 blocks of 20 trials each before commencing on the picture-naming test.

After completing the picture-naming test, participants began a practice session of 4 blocks of 10 trials each on the proper experiment. Each block tested for a combination of one RCI and one CSI at a time. All combinations of RCI (160 ms or 900 ms) and CSI (150 ms or

2,000 ms) were practised. Participants received instruction during practice trials to verbally identify the cue mappings. For example, they were told to identify the green N cue as *name the picture* and the red R cue as *do not read the word, but name the picture.* Emphasis was placed on imparting the instruction to decode incongruent cues as a two-step process: to stop the irrelevant task, and then to proceed to the relevant one. This was to discourage participants from mapping incongruent cues directly to the incongruent task. If for instance a participant associated red Rs to the naming task, that is, to skip encoding the reading schema that would otherwise have been triggered by the letter "R", the measurement of suppression imposed on the reading task would be confounded since the reading schema was not activated.

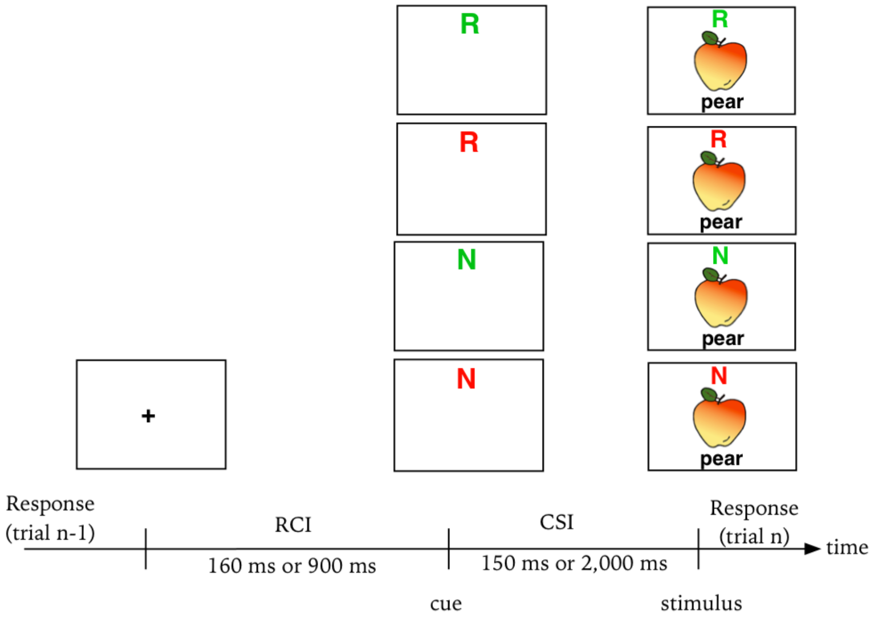


Figure 20: Schematic of related trials with congruent and incongruent cues.

The experiment began with a fixation cross that was displayed for 160 ms (short RCI condition) or 900 ms (long RCI condition). A cue then preceded the picture-word stimulus by 150 ms (short CSI condition) or 2,000 ms (long CSI condition). The cue, picture, and word were displayed until a response was made or for a maximum of 4,000 ms, after which a blank screen appeared for 1,000 ms before the next trial began. RCI and CSI values were blocked such that the first block ran the RCI-CSI combination of, in ms, 160-2,000, the second, 160-150, the third, 900-2,000, and the fourth, 900-150. Participants completed two such cycles.

This order of blocks was counterbalanced for half the participants in each group. In each block of 64 trials, there were equal numbers of congruent and incongruent trials. For each of these trial types, there were equal numbers of related and unrelated trials. Four cues appeared with equal frequency throughout the block and picture-word stimuli order was pseudorandomly sequenced such that no stimulus appeared twice in the same block. In total, participants worked through 8 blocks and 512 trials.

Data Analysis and Results

Errors were first identified from the data. These were non-responses and speech dysfluencies (hesitations, fillers, repaired utterances, non-speech sounds). Aside from these, three other types of responses in each task were scored as errors. For the naming task, errors were (a) picture names that differed from a list of normed names (Appendix D), (b) word-reading (c) word-reading wrongly. For the reading task, errors were (a) reading a different word other than the one displayed on the screen, (b) picture-naming and (c) picture-naming wrongly. Trials following errors were excluded from the analyses of response latencies which is consistent with the practice of Monsell and his colleagues. Following this, reaction times 2 standard deviations above the mean were trimmed from the data. 4.7% of all trials were removed. An alpha level of .05 was used for all statistical tests and a Bonferroni adjustment was performed for multiple comparisons.

Table 5

Mean of naming latencies in milleseconds (M), standard deviations (SD) and error rate (%) of each task by CSI, relatedness, congruency, and language group.

				Monolinguals			Bilinguals		
Task	CSI	Relatedness	Congruency	*M* (ms)	*SD*	Error (%)	*M* (ms)	*SD*	Error (%)
Baseline (picture-naming)	- -	-		633	41	0	702	73	0
Naming	150	Unrelated	Congruent	873	132	15	950	130	16
			Incongruent	932	144	21	980	144	21
		Related	Congruent	909	155	20	963	122	24
			Incongruent	962	140	22	982	127	24
	2,000	Unrelated	Congruent	635	67	17	707	124	15
			Incongruent	618	55	10	699	87	8
		Related	Congruent	654	69	13	712	85	13
			Incongruent	660	88	13	711	90	14
Reading	150	Unrelated	Congruent	667	81	4	726	107	4
			Incongruent	806	148	13	786	122	8
		Related	Congruent	654	93	3	709	119	4.5
			Incongruent	786	136	10	777	113	8
	2,000	Unrelated	Congruent	458	52	1	460	55	1
			Incongruent	464	64	1	471	59	2
		Related	Congruent	452	52	0	461	61	0
			Incongruent	460	59	2	472	53	3

Error data was first analysed. A mixed ANOVA of the errors from the naming task with the factors language group, relatedness, congruency, and CSI showed a main effect of relatedness, F (1, 22) = 6.27, p = .02. There were no other significant effects or interactions (all ps > .05). A mixed ANOVA of the errors from the reading task with the factors language group, relatedness, congruency, and CSI showed that the bilingual group made marginally more errors than the monolingual group, F (1, 22) = 2.13, p = .064, a main effect of congruency, F (1, 22) = 30.42, p < .001, and CSI, F (1, 22) = 57.41, p = .003.

Baseline picture-naming latencies were submitted to an independent samples *t*-test to check for possible group differences. Results uncovered an unanticipated bilingual speed disadvantage that showed that monolinguals were significantly faster at naming pictures than bilinguals, *t* (22) = 2.84, *p* = .009. This indicated that there were pre-existing picture-naming differences between monolinguals and bilinguals. Following Bialystok, Craik and Luk (2008b) who submitted vocabulary scores as a covariate to assess group differences between monolinguals and bilinguals, we used the analysis of covariance (ANCOVA) to assess group differences in the naming task and submitted as the covariate baseline picture-naming RT.

In the paragraphs that follow, the data analysis will take this structure. First, RCI effects, as planned, were assessed. If they were not found to significantly RT, this variable would be collapsed in subsequent analyses. Next, in order to separately assess the effects of interference suppression and response inhibition, we first assessed if they interacted. Finally, these effects were each assessed in each task.

As planned, RCI effects were first assessed. A mixed three-way ANCOVA with between-groups factor language group (monolingual, bilingual) and within-groups factors RCI (short, long) and CSI (short, long) was performed on RTs from the naming task. Results showed no group differences, *F* (1, 21) = 1.29, *p* = .269, and that naming was significantly slower when the CSI was short than when it was long, *F* (1, 21) = 4.61, *p* = .044. RCI duration did not have a significant influence on naming performance, *F* (1, 21) = 2.39, *p* = .137. RTs of the reading task were submitted to a mixed three-way ANOVA (language group × RCI × CSI). Reading was significantly slower when the CSI was short than when it was long, *F* (1, 22) = 344.77, *p* < .0001, and there was no main effect of RCI, *F* (1, 22) = .09, *p* = .76. Results also showed that monolinguals did not read differently from bilinguals, *F* (1, 22) = .37, *p* = .552.

These results showed that only the CSI, and not the RCI, manipulation resulted in significant differences in task performance. Subsequently, RCI conditions were collapsed and CSI conditions were kept separate.

We were primarily interested in the interference effect and response inhibition effect. The interference effect was the result of a delayed verbal response caused by the presence of a semantically related distractor and therefore the variable of interest was *relatedness*. The response inhibition effect was the result of stopping a planned response. When the cues were incongruent (a red R or N), participants had to withhold the task triggered by the letter salience and respond to the unindicated task. To assess response inhibition in the naming task, the variable of interest was *congruency*. Examining each of these effects separately requires the relatedness variable to operate independently of the congruency variable. Therefore, we first assessed if the two variables interacted in each task.

RTs of the naming task were submitted to a mixed four-way ANCOVA involving language group (monolingual, bilingual), relatedness (related, unrelated), congruency (congruent, incongruent), and CSI (short, long). The ANCOVA showed that monolinguals and bilinguals did not perform differently, $F\ (1, 21) = 1.27$, $p = .273$. There was a main effect of CSI, $F\ (1, 21) = 4.59$, $p = .04$, indicating that the short CSI condition was significantly more difficult than the long CSI condition. Surprisingly, relatedness of a distractor did not affect naming significantly, $F\ (1, 21) = 3.12$, $p = .092$. No other interactions or effects were noted (all *ps* > .05).

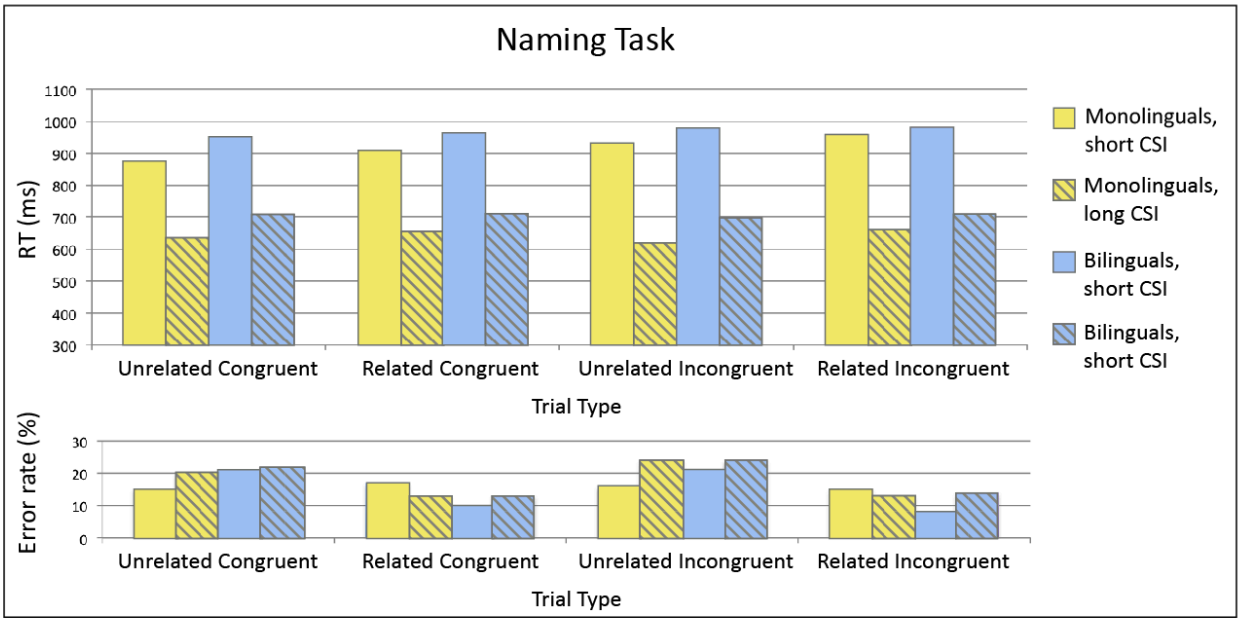


Figure 21: The mean reaction time (ms) and the error rate (%) of monolinguals and bilinguals in the naming task plotted by trial type along the horizontal axis. Related and unrelated conditions refer to distractor that accompanied the picture. Congruent and incongruent conditions refer to the nature of the cue that preceded the picture (e.g., a red R is an incongruent naming cue).

There was also a mixed four-way ANOVA (language group × relatedness × congruency × CSI) involving the same variables on RTs of the reading task. Results showed that monolinguals did not read words differently from bilinguals, *F* (1, 22) = .37, *p* = .55, and that reading was slower in the short CSI than long CSI, *F* (1, 22) = 344.77, *p* < .0001 for both groups. There was a significant interaction of CSI and congruency, *F* (1, 22) = 22.09, *p* < .0001, and a three-way interaction among language group, congruency, and CSI showed a marginal trend towards significance, *F* (1, 22) = 3.82, *p* = .064. Incongruent reading trials were significantly slower to carry out than congruent reading trials, *F* (1, 22) = 29.91, *p* < .0001, indicating that all participants took longer to suppress a naming schema before reading the distractor. Relatedness of a word to a picture did not affect reading speed, *F* (1, 22) = 2.16, *p* = .16. No other effects and interactions were noted (all *p*s > 0.1). After applying a Bonferroni adjustment (.025), the significant CSI × congruency interaction survived, as did the significant effect of congruency (*p*s < .025).

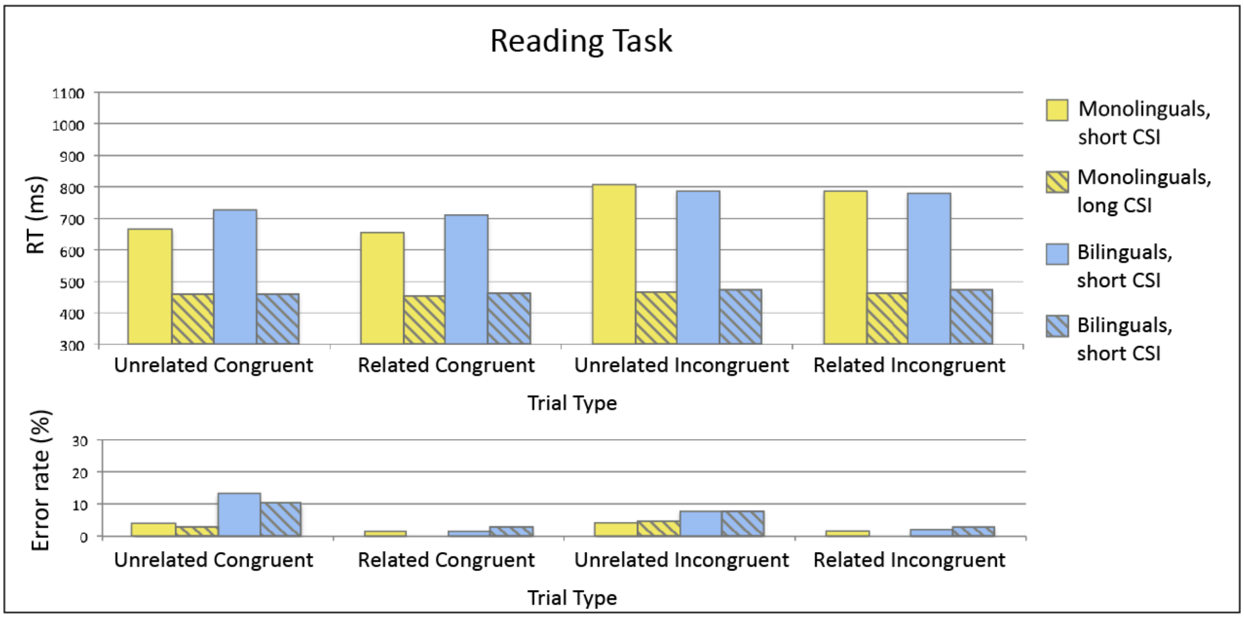


Figure 22: The mean reaction time cost (ms) and the error rate (%) of monolinguals and bilinguals in the reading task plotted by trial type along the horizontal axis. Related and unrelated conditions refer to distractor that accompanied the picture. Congruent and incongruent conditions refer to the nature of the cue that preceded the picture (e.g., a red R is an incongruent naming cue).

To assess the interference effect in the naming task, related congruent trials were contrasted with unrelated congruent trials. A related distractor increased monolinguals' RT by an average of 36 ms (909 – 873 = 36) and bilinguals' RT by an average of 13 ms (963 – 950 = 13) in the short CSI condition. Therefore monolinguals experienced a greater cost of 23 ms when a related distractor was present. This was also the case at the long CSI. A related distractor increased monolingual RT by an average of 19 ms (654 – 635 = 19 ms) and bilingual RT by an average of 5 ms (712 – 707 = 5 ms). Therefore it was costlier by 14 ms for monolinguals to perform a related trial compared with bilinguals. A mixed three-way ANCOVA (language group × relatedness × CSI) revealed that these differences were not significant, F (1, 21) = 1.46, p = .24, but showed a main effect of CSI, F (1, 21) = 5.01, p = .036, indicating that the short CSI condition versus the long CSI condition delayed RT significantly. The lack of a main effect of relatedness, F (1, 21) = 1.67, p = .21, as well as any significant interactions (all *p*s > .05) showed that monolinguals and bilinguals were not different in their abilities to suppress interference from a distractor, whether it was semantically related or not.

RTs of the reading task were next assessed for interference effects. Monolinguals actually read more quickly in the related condition. This was both at the short CSI (654 – 667 = -13 ms) and long CSI (452 – 458 = -6 ms). This was also the case for bilinguals at the short CSI (709 – 726 = -17 ms), and the long CSI (461 – 459 = 2 ms). A mixed three-way ANOVA on language group, relatedness, and CSI showed that none of these differences between the two groups were significant, F (1, 22) = 1.48, p = .237. The effect of a related distractor on reading the word was not significant, F (1, 22) = 3.09, p = .093.

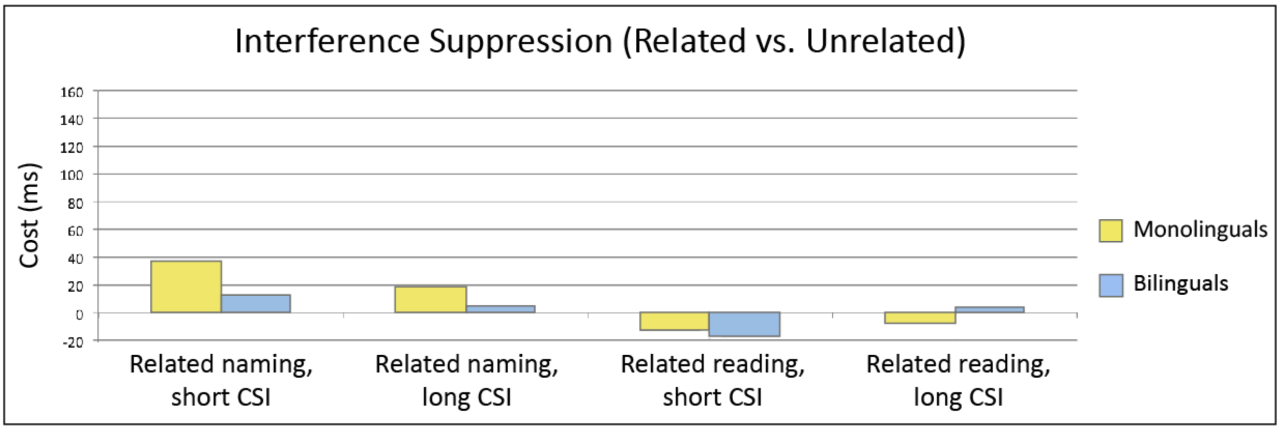


Figure 23: The mean reaction time cost (ms) representing the interference effect (Related Congruent – Unrelated Congruent) in the naming task and the reading task of monolinguals and bilinguals.

To assess the response inhibition effect in the naming task, unrelated congruent trials were contrasted with unrelated incongruent trials. A mixed three-way ANCOVA (language group × congruency × CSI) was carried out on the RT of the naming task. This did not show any effect of congruency, *F* (1, 21) = .02, *p* = .896, or group, *F* (1, 21) = 1.671, *p* = .21, and a marginal effect of CSI, *F* (1, 21) = 3.797, *p* = .065. It was noted however that the incongruence of a naming task caused monolinguals to increase their RT by an average of 59 ms (932 – 873 = 59) and this was an average of 30 ms (980 – 950 = 30) for the bilinguals.

To check for effects of response inhibtion in the reading task, a mixed three-way ANOVA on the factors language group, congruency, and CSI showed that reading in both groups were significantly affected by incongruent trials, *F* (1, 22) = 17.73, *p* < .001, and CSI, *F* (1, 22) = 286.64, *p* < .001. At the shorter CSI, incongruent reading trials were much slower to perform, *F* (1, 22) =10.48, *p* = .004, and the lack of a significant three-way interaction among congruency, CSI, and group, *F* (1, 22) = 2.3, *p* = .144, showed that this difficulty was experienced by both monolinguals and bilinguals. Though statistically not significant, score differences revealed a numerically greater response inhibition effect for monolinguals (806 – 667 = 139 ms) than bilinguals (786 – 726 = 60 ms) at the short CSI. This difference was reduced at the long CSI where incongruency numerically increased RT less in monolinguals (464 – 458 = 5 ms) than it did in bilinguals (471 – 460 = 11 ms).

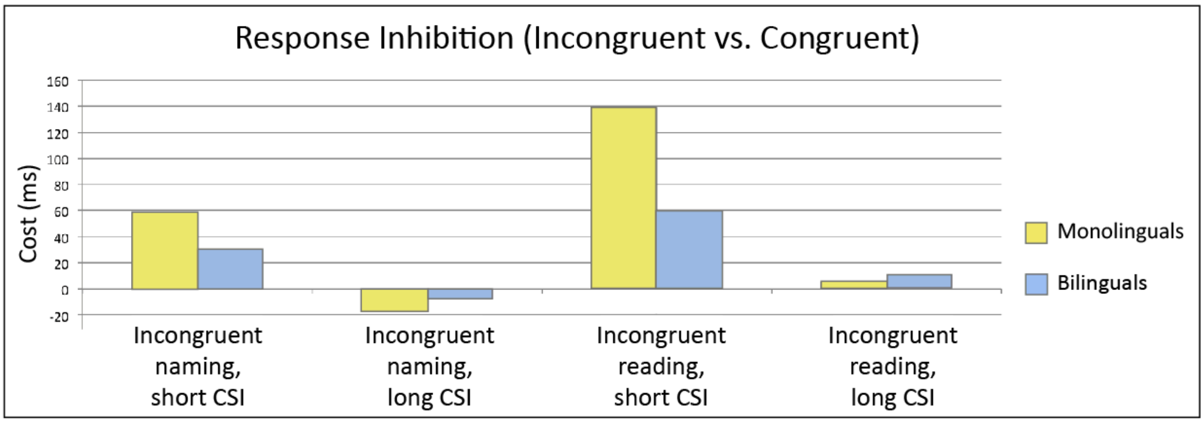


Figure 24: The mean reaction time cost (ms) representing the response inhibition effect (Unrelated Incongruent – Unrelated Congruent) in the naming task and the reading task of monolinguals and bilinguals.

Discussion

This experiment was conducted to determine whether the specific experience of having to suppress interfering words as part of daily bilingual communication boosted performance in a language interference task. Participants performed a cued PWI task that tested for language interference suppression ability as well as language response inhibition ability. These two abilities were respectively tapped into using stimuli that contained a potentially interfering distractor or a cue that could indicate the irrelevance of a task.

Certain observed effects were not surprising. Given that reading was the more dominant of the two tasks, the experiment showed significantly lower reading RT than naming RT for both groups. The shorter CSI allowed participants less time to process the cue than the longer CSI, therefore significantly higher RT for each task was incurred in the shorter CSI than the longer CSI condition for both groups. Other data however yielded some unexpected results. First, the bilingual group, despite their privileged educational background, showed a naming disadvantage in baseline analyses. Second, related distractors had no significant effect on naming in both groups. This result is not in agreement with the semantic interference effect commonly reported in traditional PWI tasks (e.g., Hermans et al., 1998; Starreveld & La Heij, 1995). Third, despite the dominance of the reading task, the impact of an incongruent cue was much greater on this task (a red N for reading) than it was on the naming task (a red R for naming), implying that suppressing a naming response was harder than suppressing a reading response in incongruent conditions. Above all, there were no group differences in interference suppression trials and response inhibition trials, and no group differences whether the CSI was short or long, indicating that the basis of the bilingual advantage may be misunderstood. We begin our discussion with the expected results – the lower RT incurred on the reading task and the effect of the CSI across both tasks – and then move on to the bilingual naming deficit, the influence of relatedness and congruency, and the null finding on group differences.

The ease with which the reading task was carried out relative to the naming task may be attributed to the widely accepted view that the word recognition process is a highly-practiced one (see Macleod, 1991). Evidence for the strong association of a reading response to word stimuli comes from research on the Stroop effect – naming a colour ink is harder if it is displayed in a word which happens to spell a conflicting colour than when it does not (Allport et al., 1994; Macleod, 1991). This response is directly related to the skilled habit of reading, which reinforces the chain of processes involved in identifying a letter string, and linking the composite string to a matched phonology and meaning (Dijkstra & van Heuvan, 2002). In contrast, the process of picture-naming requires the identification of an object and retrieval of its phonological code and meaning through the semantic route. Compared with graphemic analysis, naming an object through perceptual analysis is a more voluntary, and therefore slower, process. We had also predicted that a shorter CSI would lead to an increase in RT; this was aptly demonstrated. The result of impaired performance on shorter relative to longer CSIs is well-supported in the task switching literature (Altmann, 2006; Meiran et al., 2000; Monsell & Mizon, 2006).

The bilingual naming deficit cannot be due to the demands of performing under a time constraint as even with ample time, bilinguals still lagged behind monolinguals. That our monolingual and bilingual sample were drawn from the university student population, who would largely be matched on age, educational level, social habits, and their use and command of English, makes sample variance an unlikely explanation. The disparity between the groups may therefore reflect inherent differences between monolingual and bilingual language processing, an interpretation that is supported by at least two studies also reporting a bilingual deficit in picture-naming (Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Ivanova & Costa, 2008). This result suggests that bilinguals activated the non-target language during target word retrieval which delayed their response rates (Bialystok, 2008; Green, 1998). A spreading activation model of the bilingual lexicon (Green, 1998; La Heij, 2005) explains this by assuming that under any circumstance a semantic representation is activated, the activation necessarily spreads to both the first (L1) and the second language (L2). In the IC model, the irrelevant language is suppressed when the selection system recognises that they are not part of the task goal. Thus, in having to suppress an extra language, bilinguals needed more time to complete their retrieval process. An additional question is how Elston-Guttler et al. (2005) had not found interference effects in their sample who performed under L2-only material. The stimuli used in their study were designed such that targets were part of whole sentences in the same language, and thereby provided a stronger context within the target language for participants to decode meanings. Elston-Guttler et al. showed that the sentential context was critical in controlling L1 interference and thus, the lack of a sufficient L1-based context may explain why, despite considering external factors that would mitigate L2 competition in the cued PWI task, the bilinguals in our experiment still showed a disadvantage in L1 naming.

We now address interference suppression (distractor relatedness) and later move on to response inhibition (cue congruency). The motivation for examining semantic interference across monolinguals and bilinguals was to verify if bilingualism boosted the ability to handle language interference. Results showed no group differences on picture-naming speed regardless of the distractor, indicating that monolinguals and bilinguals did not perform differently in our measure of language interference suppression. While this result is less surprising based on the null result we got from Experiment 1, we had expected related distractors to significantly affect naming, but this was only marginally so for both groups. This may be explained by a result in our error data analysis for the naming task. There was a main effect of relatedness which indicated that more mistakes were committed on unrelated trials than related ones. This suggests that the participants may generally have found the task difficult which would have increased the RT of unrelated trials. Consequently, the impact of related trials was reduced. The fewer number of errors made on related trials suggests that participants exercised more care on these trials. The issue of relatedness aside, the important result for this is that bilinguals were not better at suppressing language units than monolinguals.

The results for response inhibition were not straightforward. RT reliably increased in both groups when the reading task was preceded by an incongruent cue (a red N), but the naming task remained unaffected under the same condition (a red R). Since the incongruence of a trial represents the suppression of the irrelevant task, and since incongruent reading was harder than incongruent naming, the result implies that suppressing the naming task was more effortful than suppressing the reading task. This seems to contradict the observation that the reading task is the more highly practiced one, and should therefore be more difficult to suppress.

The idea of switching between two tasks may help to explain why, relative to congruent trials, incongruent reading was more difficult than incongruent naming. In this area of research, it has been observed that when one switches from one task to another, the reaction time taken to complete the new task is longer than that of the previous task. This switch cost has been attributed to the idea of task set inertia advanced by Allport et al. (1994). They showed, and several language switching experiments have confirmed (Jackson et al., 2001; Meuter & Allport, 1999), that when switching between two tasks of unequal proficiencies, the switch cost is larger for the more proficient than the less proficient task. Allport et al. argue that task switching necessitates the suppression of the non-target task when the target task is carried out. Without properly suppressing the non-target task, performance of the target task may suffer. It follows that the stronger the task is, the greater the suppression that must be applied to it, if the weaker task is to proceed uninterrupted. The IC model (Green, 1998) endorses this theory and states that in the domain of language tasks, it is the competition between, and the suppression of, language schemas of different strengths that gives rise to the switch cost.

Following this account by task- and language switching, incongruent trials in this experiment may actually reflect the time taken to unsuppress a relevant language task schema. As part of the experimental procedure in ensuring that participants did not map incongruent cues directly to their rival tasks, instructions were imparted to participants such that they were strongly encouraged to identify congruent trials as a one-stage process (e.g., “Name the picture,” for a green N) and incongruent trials as a two-stage process (e.g., “Do not name the picture. Read the word,” for a red N). This presumably would lead to the desired effect of triggering the schema associated with the cue letters after which participants had to decide whether or not the schema was relevant. Congruent trials are performed easily enough since the cues are directly mapped to the required response. Incongruent trials however, by design, have cues with letter forms that would have involuntarily triggered the activation of the irrelevant task. Since according to Allport et al. (1999) and Green (1998), the activation of one task will lead to the suppression of the other competing task, then, when faced with an incongruent cue, participants would have triggered the irrelevant task and applied suppression to the target task. Once incongruent cues were completely processed and the relevance of the target task made aware, participants then had to unsuppress the target task and proceed to select a response. As the reading task was the stronger of the two tasks, in unsuppressing it, participants incurred a larger cost than they would have unsuppressing the naming task. Therefore the data in Figure 24 may be interpreted as such: restoring a previously suppressed reading task took longer than restoring a naming task suppressed.

Do incongruent trials then measure language response inhibition? If theories of task and language switching are correct, which our results on incongruent trials seem to suggest, then these trials do indeed require the suppressing of a non-target task, but this process needs to be disambiguated from that of unsuppressing a target task. There is the possibility of analysing error scores which indicate the percentage of responses that participants had failed to suppress a response, however, these errors would be confounded with those committed due to task or language switching difficulties. A viable avenue for future research in this area is to employ advanced techniques that are able to decompose these processes along a timeline.

In line with this suggestion is neuroimaging research that has focused on disentangling non-language task control using the Wisconsin Card Sorting Test (WCST) (Graham et al., 2009; Monchi, Petrides, Petre, Worsley, & Dagher, 2001). The WCST is believed to tap into processes elicited by the go/no-go task and task switching (Konishi et al., 1999). In the WCST, participants are instructed to figure out a rule that would correctly match a target card to one of four presented cards. Each of the four cards bear icons that match the ones on the target card either in shape, colour, or numerosity. The rule changes without warning and depending on which one is relevant at the time, participants are given feedback on whether they have sorted a card correctly. Thus, critical trials are when the rule changes, and, one trial after receiving negative feedback, participants successfully suppress the tendency to sort to a previously relevant dimension, and switch over to (i.e. unsuppress) another dimension. Current literature supports the notion that neural circuits supporting a switch in sorting are distinct from those suppressing the irrelevant dimension (Graham et al., 2009; Monchi et al., 2001) indicating a dissociation between suppression and unsuppression processes. A prudent application of this method for our purposes requires the construction of a linguistic version of tasks such as the WCST that may be administered across monolinguals and bilinguals before any conclusion on the interaction between suppression and unsuppression processes can be reached.

Finally, we consider our overall null finding on group differences. A clear indication of this is that monolinguals and bilinguals performed equivalently on both low and high task demands, as reflected in picture-naming under long and short CSIs. Based on research showing a pronounced bilingual advantage under conditions of high task demands (Bialystok et al., 2004; Costa et al., 2009: Martin-Rhee & Bialystok, 2008), we had expected that the bilingual group would perform better than monolinguals under the short CSI, but this was not shown. Therefore, across Experiments 1 and 2, bilinguals did not show an advantage in either low or high task demands, regardless of linguistic content. The straightforward interpretation of this is that bilinguals are simply not better than monolinguals in suppressing interference. This explanation is however not reconcilable with the bilingual advantage seen in children

(Bialystok & Codd, 1997) or in older adults (Bialystok et al., 2004, 2008). Therefore, it appears that if there are differences between monolinguals and bilinguals as previous work suggests, the bilingual advantage may originate from the practice of a cognitive skill other than interference suppression; the advantage in interference suppression is likely to be a product of the exercise of this skill. Alternatively, it could be that RT-based tasks may not be sufficient in detecting monolingual and bilingual differences in the young adult population. We discuss these alternatives in the general discussion.

In the next chapter, we turn to investigating language control at the level of schemas.

CHAPTER 7 – EXPERIMENT 3

Experiment 3A

Overview

Logan and Bundesen (2003) pointed out that task switching reaction time data might not be capturing task switching processes as believed, and that the problem lay in the use of an explicit cue to specify a to-be-performed task. This raised possible concerns about previous language switching research which relied heavily on the traditional cued task switch paradigm (Figure 25).

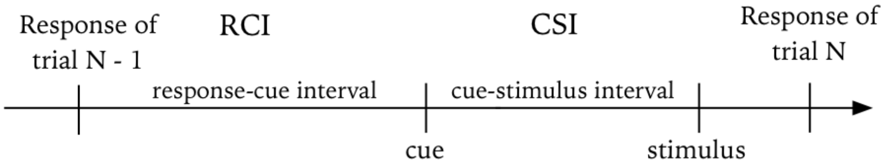


Figure 25: The cued switching paradigm where participants respond to the stimulus according to the cue that precedes it.

In the cued task switching procedure, participants are exposed to a series of stimuli that are each preceded by a cue indicating one of two possible tasks. This design yields two types of trials: task repetitions and task switches. If the same cue appears from one trial to the next, the task is repeated; if the cue is different, then a switch in task occurs. The finding with these two types of trials is that it takes a longer time to switch into a new task than to repeat it (Monsell & Mizon, 2006). According to Monsell (2003), during task performance, extra time will be needed to mentally reconfigure to new task settings when a task change is implemented. This cost in switching tasks, the switch cost, is believed to be a measure of how an individual exerts voluntary control involved in a task change. The relatively simple method of capturing the duration of task control forms part of the appeal of the tasking switch paradigm with decades of research having been invested in examining the switch cost. However, the criticism raised against the procedure is that for each task switch that occurs, a cue switch also occurs. When the task repeats itself, the cue repeats itself too. Therefore what appears to be an index of control processes may actually be a consequence of cue switching processes (Logan & Bundesen, 2003).

To find out if a change of cue had an impact on performance, Logan and Bundesen (2003, Experiment 3) used a novel task switch design that allowed them to observe task conditions unaffected by cue switches. Instead of the using one cue per task, two cues were assigned to each task. This enabled the separation of task repetitions resulting from a sequence of two identical cues, and task repetitions resulting from a sequence of two unique cues. The authors found that when contrasting these two types of sequences, time latencies for the former kind of task repetition trials were quicker than the latter, suggesting a substantial contribution from cue processing. This effect was observed in separate studies (Horoufchin et al., 2011; Monsell & Mizon, 2006; Schneider & Logan, 2005), confirming the part that cue processing played in task switching. Furthermore, uniquely cued task repetition latencies approached that of task switch latencies, leading the Logan and Bundesen to conclude that a significant portion of switch costs reflected cue switch processes, and not control processes as previously thought.

Using Logan and Bundesen's (2003) 2:1 cue-to-task mapping method, and by incorporating a range of cue-stimulus intervals (CSI), Monsell and Mizon (2006) carried out an experiment testing the idea that the task switch paradigm measured actual task switching processes and did not simply reflect cue switches. The aim of the experiment was to demonstrate that pure cue switches, that is, the condition where task repetitions follow from a sequence of unique cues, were distinct from task switches. Monsell and Mizon further claimed that if switch costs reflected the control processes necessary for implementing a task change, they should decrease if participants were given more time to prepare for a task. The time when participants could begin actively preparing for the next task was when the cue appeared, which was the CSI. In using a range of CSIs, Monsell and Mizon planned to track the behaviour of switch costs as the time available before the onset of the stimulus increased.

Their results showed two effects. First, task switches were distinct from cue switches (where the task did not change), indicating that it was possible to control for cue-switch effects. Next, as the CSI increased, switch costs decreased. This was interpreted as the improvement in performance brought about by participants making use of the CSI to prepare for the next task; the greater the CSI, the lower the cost it took to switch into a new task. This reduction of switch costs has been taken to be an empirical signature of a participant exercising voluntary control over cognitive processes, a process that is known as *task set reconfiguration* (Monsell, 2003; Monsell & Mizon, 2006).

Monsell and Mizon (2006) however pointed out that not all studies managed to show a reduction in switch costs over at a longer CSI (Altmann, 2006; Philipp et al., 2007), calling into question if the processes occurring within the CSI were devoted to reconfiguration. Nevertheless, there was a methodological option to encourage reconfiguration within the CSI. In another experiment, Monsell and Mizon showed that switch costs were most prominent when the probability of switches within a block of trials was reduced to 25% of all trials. They reasoned that the lower number of switches induced participants to adopt a strategy beneficial to task repetition performance such that when a switch in task was unexpectedly encountered, huge costs were incurred.

Thus far, task switch research has shown the value of

(i) using two cues per task to address cue confounds,

(ii) using a range of CSIs to track switch costs which will in turn give insight into control processes, and

(iii) reducing the probability of changing tasks within a block to 25% so that the cognitive processes involved in task switching can be optimized.

In contrast to progress made in task switch research, language switch research paid little attention to the above developments and the fact that switch data could indeed be confounded by cue switches (Logan & Bundesen, 2003). It remained unknown what language processes go on during a language switch, if cue processes affected reaction time, or if reconfiguration of a language task set occurred. Furthermore, the emphasis on language dominance in language switching research added an additional layer of complexity to unconfounding cue effects as this implied differential patterns of language switching in bilinguals with different language proficiencies.

In line with the developments in task switch research, the current experiment aimed at filling a gap in language switching research with a novel examination of language switch data that was unconfounded by cue-switch effects. It adopted the above listed methodological measures that safeguarded against the pitfalls of the traditional task switch paradigm, and applied them to the language domain. The questions it aimed to answer were:

1. Can switch costs be demonstrated in a bilingual's two languages after cue-switches have been taken into account?
2. Given that a range of bilinguals exists and that dominance has been previously shown to affect switch costs, do balanced bilinguals switch between their two languages differently to unbalanced bilinguals, once cue switching has been controlled for?
3. Following what seems to be an index of exercising control on cognitive systems (task set reconfiguration), can a reduction in language switch costs over an increasing CSI be demonstrated once cue switching has been controlled for?

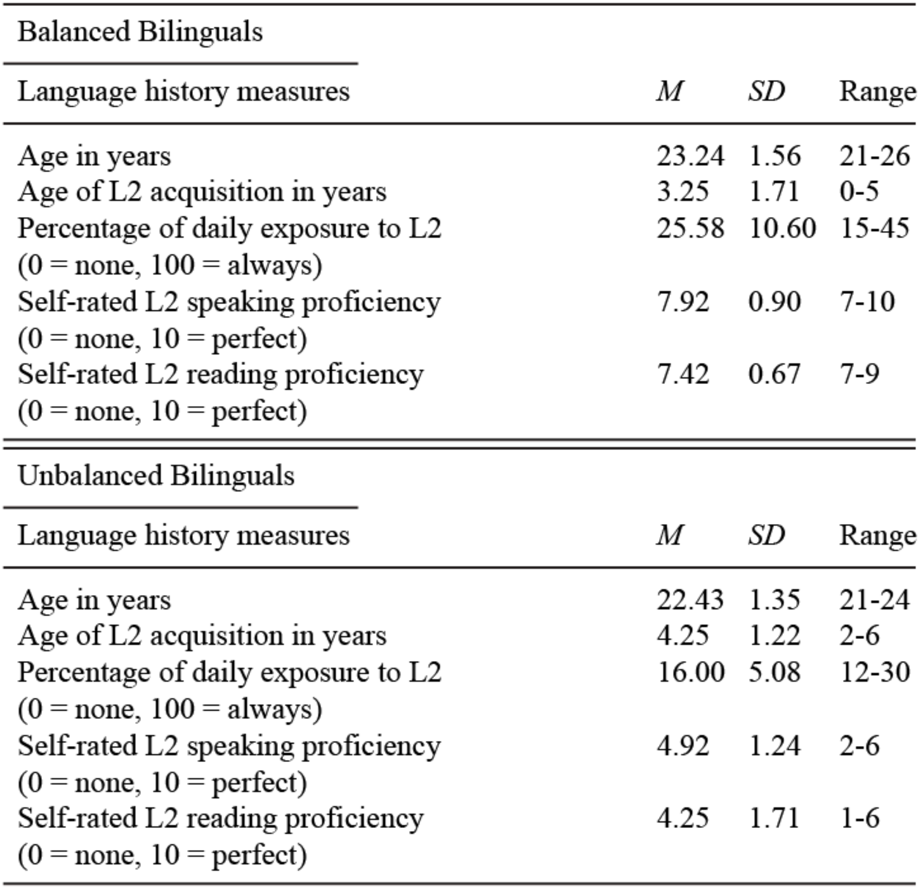
Method

Participants

24 English-Mandarin bilinguals from the National University of Singapore received modular credit or monetary payment for their participation. Subjects gave informed consent; approval for the study protocol was obtained from the local institutional ethics commitee. Participants were divided into unbalanced and balanced bilingual groups using the LEAP-Q (Marian et al., 2007), as described in Experiment 1. All bilingual participants were exposed to English and Mandarin from the age of 2 to 6 years, and learned them as subjects in school beginning at the age of 6 to 7 years. English was the medium of instruction except for lessons in Mandarin. This form of instruction lasted till the participants were 17, after which they enrolled into university and stopped taking formal language instruction. The medium of instruction at university was English. Unbalanced bilinguals (n = 12, mean age = 22.43, *SD* = 1.34, range 21-26) reported that they mostly spoke English and used Mandarin in particular contexts such as speaking with the elderly in Singapore, with their Mandarin-speaking friends, or when ordering food, while balanced bilinguals (n = 12, mean age = 23.24, *SD* = 1.56, range

21-26) indicated that they used both Mandarin and English frequently. All balanced bilinguals came from Mandarin-speaking families.

Tables 6a and 6b
The language history and proficiency characteristics of balanced bilinguals (table 6a, top) and unbalanced bilinguals (table 6b, bottom) in Experiment 3A (see Appendix E).



Balanced Bilinguals

Language history measures	*M*	*SD*	Range
Age in years	23.24	1.56	21-26
Age of L2 acquisition in years	3.25	1.71	0-5
Percentage of daily exposure to L2 (0 = none, 100 = always)	25.58	10.60	15-45
Self-rated L2 speaking proficiency (0 = none, 10 = perfect)	7.92	0.90	7-10
Self-rated L2 reading proficiency (0 = none, 10 = perfect)	7.42	0.67	7-9

Unbalanced Bilinguals

Language history measures	*M*	*SD*	Range
Age in years	22.43	1.35	21-24
Age of L2 acquisition in years	4.25	1.22	2-6
Percentage of daily exposure to L2 (0 = none, 100 = always)	16.00	5.08	12-30
Self-rated L2 speaking proficiency (0 = none, 10 = perfect)	4.92	1.24	2-6
Self-rated L2 reading proficiency (0 = none, 10 = perfect)	4.25	1.71	1-6

In Experiment 1, we followed the classification ratings of Kaushanskaya and Marian (2009). This was to have balanced bilinguals have a maximum age of 5 years when they began acquiring L2, be exposed to L2 daily for at least 12%, and on average rate their speaking and reading proficiency as 7 or greater, out of a scale of 10. The unbalanced bilinguals in this study rated themselves below 7 for their speaking and reading L2 proficiency. However, they were exposed to L2 for greater than 12%, and had begun learning L2 at a mean age of 4.25 years. However, these ratings are closely matched with the high proficiency bilinguals in Kaushanskaya and Marian's study. These ratings may be inflated because of the unique language environment these bilinguals, all Singaporeans, lived in. As noted by Lim, Liow, Lincoln, Chan, and Onslow (2008), Singaporean children live in a multicultural society and are exposed to at least two of the four official languages (English, Malay, Mandarin, and Tamil). Despite this vibrant community however, Pakir (1991) noted more than two decades ago that the education in Singapore was gearing towards an English-speaking nation. Presently, it is acknowledged that an increasing number of Singaporeans are using English as their main language (Wee, 2002). Therefore, the L2 exposure and L2 learning age of unbalanced bilinguals may reflect the result of living in Singapore, rather than a high proficiency in L2.

Cues and stimuli

Cues

Two cues were each assigned to a Mandarin task (M) and English task (E). A total of four cues E1, E2, M1, and M2 (Figure 25) were used in the experiment. This design yielded three types of two-trial sequences, cue-switch-only, no-switch, and both-switch, for each language task. These trial types are described below.

Figure 25: The four language cues E1, E2, M1, and M2 used in Experiment 3A. The two left symbols cued naming in English, and the two right symbols cued naming in Mandarin. Cue design was based on the English letter form "e" and Mandarin character "中" ('zhong', to mean "Mandarin" in the compound noun 'zhongwen' which means "Mandarin language", in Mandarin). This was to increase their salience so that participants did not have to hold arbitrary cue-to-task mappings in memory with less transparent symbols.

Cue-switch-only trials

In the first trial type, the cue changed and the language repeated. A cue-switch-only trial measured the time taken to repeat a task after it followed a different cue. For example, in the experiment, considering only correct responses, this would be repeating picture-naming in English following a cue different from the previous trial. For each language task, and in terms of cues E1, E2, M1, and M2, cue-switch-only sequences can be represented as follows:

English task	E1-E2, E2-E1
Mandarin task	M1-M2, M2-M1

Note that the trial of interest is the second trial of each pair. For example, in the E1-E2 sequence, E2 is the cue-switch-only trial.

No-switch trials

In the second trial type, the cue repeated and the language repeated, and so there were no switches in either cue or language. The trial measured the reaction time for naming a picture in the same language after it followed the same cue. There were four kinds of no-switch sequences:

English task	E1-E1, E2-E2
Mandarin task	M1-M1, M2-M2

Both-switch trials

In the third trial type, both the cue and the language changed. The trial measured the reaction time for naming a picture in a different language from the last response, following a change in cue. There were four possible both-switch trials for each language task:

English task	M1-E1, M1-E2, M2-E1, M2-E2
Mandarin task	E1-M1, E1-M2, E2-M1, E2-M2

Stimuli

The same pool of picture stimuli used in Experiments 1 and 2 was used in the current experiment but was modified for the current experiment's purpose. The original Snodgrass and Vanderwart (1980) set of 260 picture stimuli had been validated based on speakers of English. To adapt the current set for use with picture-naming in Mandarin, normed Mandarin names and ratings of the Snodgrass and Vanderwart (1980) pictures by Mandarin speakers were sourced from Liu, Hao, Li, and Shu (2011). Based on the Mandarin speakers' low ratings of name agreement and concept familiarity of 27 pictures, these pictures were replaced with line drawings adapted from Liu et al. (2011) and the International Picture Naming Project (Szekely et al., 2004). They were filled with colour and outlined in black to fit in the style with the rest of the Snodgrass and Vanderwart set. All pictures were set on a white rectangle measuring 6 cm by 10 cm.

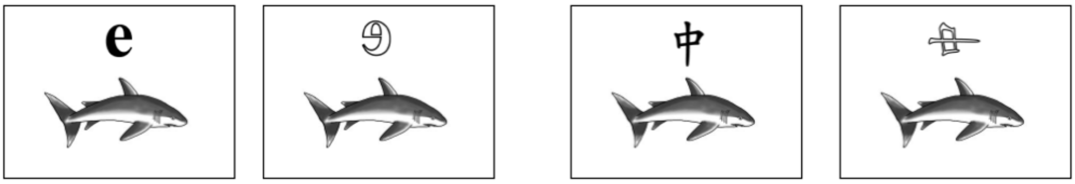


Figure 26: The possible cue-picture combinations with the stimulus 'shark' in English (two left screens) or 'shayu' in Mandarin (two right screens). With two cues assigned to one language task, it was possible to observe a cue switch while the language remained the same.

Procedure

260 picture stimuli were pseudorandomly presented over six blocks of 64 trials each such that each picture appeared a maximum of four times in total across all blocks. Following Monsell and Mizon (2006), the RCI was set at 160 ms for all six blocks. Monsell and Mizon also showed that when CSI values were jittered within a block, switch cost effects were smaller than when CSI values were blocked, possibly because participants got attuned to anticipating a range of CSIs. Therefore, to avoid a mixing effect, each of the six CSI values used in the experiment, 150, 300, 500, 800, 1,200 and 2,000 ms, were assigned to one block each (Figure 27 below). Each participant started with the block with the shortest CSI, and proceeded in block order of ascending values of CSI. Half of the participants began with the block with the longest CSI, and the other half proceeded in the reverse block order.

	RCI	CSI	No. of trials
Block 1	160	150	64
Block 2	160	300	64
Block 3	160	500	64
Block 4	160	800	64
Block 5	160	1200	64
Block 6	160	2000	64

24 cue-switch only, 24 no-switch, and 16 both-switch trials are pseudorandomly presented over 64 trials in each block

Figure 27: The design of Experiment 3A showing block order, response-cue interval (RCI) values, cue-stimulus interval (CSI) values, and the break down of trial types. Half the participants in each bilingual group sat for the experiment beginning with Block 1 and proceeded in ascending order of blocks, and the other half began with Block 6 and proceeded in descending order of blocks.

To discourage participants from adopting a strategy in response to frequent switching, the probability of both-switch trials was set to 25% of all trials in each block. Of these 25% of trials, half were language switches from English to Mandarin, and the other half from

Mandarin to English. The remaining 75% of all trials in each block were equally distributed into cue-switch-only and no-switch trials. English and Mandarin trials occurred with equal frequency in cue-switch-only and no-switch trials. All three trial types, both-switch, cue-switch-only, and no-switch, were pseudorandomly sequenced such that there were 24 cue-switch-only trials, 24 no-switch trials, and 16 both-switch trials in each block.

Each trial began with a fixation cross in the centre of the screen. After 160 ms, the cross was replaced by a cue positioned 5 cm above the origin. Depending on the block being run, a CSI of 150, 300, 500, 800, 1,200, or 2,000 ms, elapsed before a stimulus appeared. If no response was made after 4,000 ms, both the cue and picture were replaced by a blank screen for one second after which the next trial began (Figure 28 below). Thus, the inter-trial interval was 310, 460, 660, 960, 1,360 or 2,160 ms.

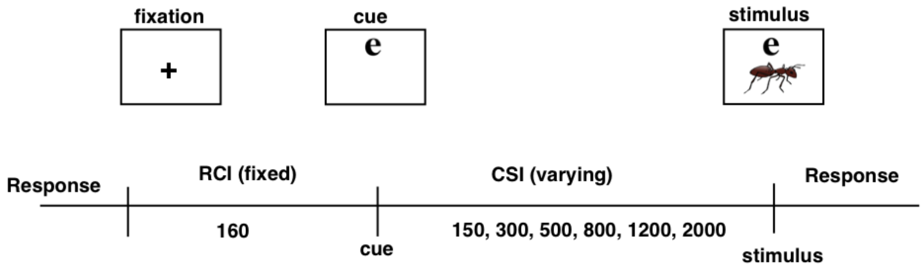


Figure 28: Schematic of a cued English language task in Experiment 3A with numerical values given in milleseconds. The response-cue interval (RCI) is fixed while the cue-stimulus interval (CSI) is varied. This design affords the manipulation of the time available to prepare for a task, once the cue is known.

Data Analysis and Results

With respect to examining language switch effects, the rationale for the planned comparisons conducted is first set out here. Since a cue switch always accompanies a task switch, it has been claimed that task switches can potentially reflect cue switches. Although previously unexplored, this is a potential confound for language switch experiments too. The current experiment maps two cues to each language task so that a cue may switch while the language repeats (in cue-switch-only trials). When this type of trial is contrasted with both-switch trials, in which both the cue and language change, the result is one that reflects only a change in language. Thus, comparisons of cue-switch-only trials and both-switch trials potentially show true language switches. To check for possible effects contributed by a change in cue, cue-switch-only trials are contrasted with trials where both cue and language repeat (no-switch trials). This method of checking for true language switch effects and possible cue processing effects was carried out using tests of analyses of variance (ANOVA). The Alpha level was set to .05.

The data were first coded. Responses were checked against a normed list of responses (Appendix D) for accuracy. Four kinds of errors were identified and excluded. These were responses made in the (a) right language but the wrong name, (b) wrong language and the wrong name, (c) wrong language but the right name, and (d) non-responses and speech dysfluencies (hesitations, fillers, repaired utterances, non-speech sounds). Errors and the trials following those errors were excluded from the analyses of response latencies. Following the procedure of Monsell and Mizon (2006), reaction time (RT) greater than two seconds were trimmed from the data. This procedure of excluding errors and trimming the RTs removed 17.2% of all trials. We also, like Monsell and Mizon, based RT analyses on the medians of correct RT of each participant. The mean of median reaction time for each CSI for each group and the mean percentage of errors at each level of CSI are shown in Tables 7a and 7b.

A mixed three-way ANOVA (group × trial type × language task) on error data showed that unbalanced bilinguals made more errors than balanced bilinguals, F (1, 22) = 5.51, $p = .028$. More errors were made in Mandarin than English, F (1, 22) = 306.75, $p < .0001$, and the fewest errors were made on no-switch trials, F (1, 22) = 23.17, $p < .0001$. There was an interaction between language task and group because unbalanced bilinguals made significantly more errors when the task was in Mandarin than when it was in English, F (1, 22) = 105.23, $p < .0001$.

Experiment 3A was designed to address a series of specific questions, the first being whether switch costs could still be observed – even after cue confounds were removed – when bilinguals switched between languages. A related question to this was whether switch cost patterns differed when bilinguals were unbalanced versus balanced.

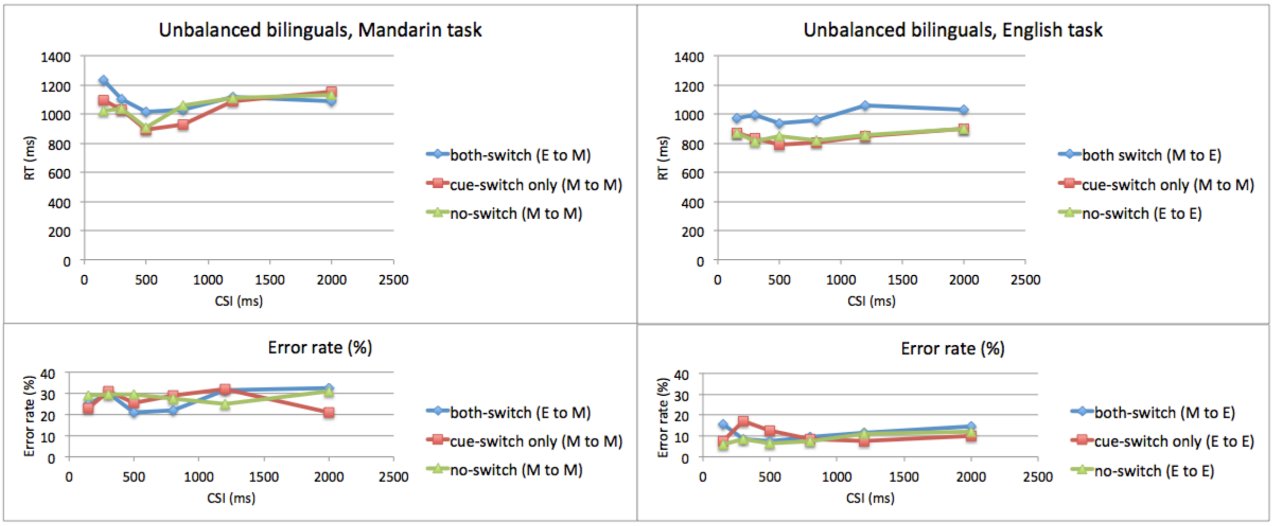
Tables 7a and 7b

Mean of median reaction time (and standard deviations in parentheses) and error rate of unbalanced bilinguals (Table 7a, top) and balanced bilinguals (Table 7b, bottom).

	Mean of median RT of Mandarin Task, *M* (*SD*)							Mean of median RT of English Task, *M* (*SD*)						
CSI (ms)	150	300	500	800	1200	2000	*M*	150	300	500	800	1200	2000	*M*
Both-switch	1235	1107	1016	1034	1120	1090	1100	973	995	938	962	1064	1031	994
	(295)	(360)	(185)	(287)	(289)	(161)		(221)	(221)	(122)	(173)	(213)	(154)	
Error (%)	25	30	21	22	31	32		16	8	7	9	11	15	
Cue-switch only	1100	1034	894	929	1087	1153	1032	867	835	790	805	851	898	841
	(258)	(252)	(147)	(141)	(267)	(181)		(139)	(201)	(123)	(114)	(134)	(128)	
Error (%)	23	31	25	29	32	21		8	17	13	8	8	10	
No-switch	1028	1041	908	1063	1111	1131	1047	874	815	850	817	855	897	851
	(241)	(248)	(177)	(221)	(173)	(189)		(132)	(149)	(129)	(109)	(114)	(121)	
Error (%)	29	30	30	27	25	31		6	8	6	8	11	12	
Switch cost (minus cue-switch effect)	135	73	122	105	33	-63	68	106	160	148	157	213	133	153

	Mean of median RT of Mandarin Task, *M* (*SD*)							Mean of median RT of English Task, *M* (*SD*)						
CSI (ms)	150	300	500	800	1200	2000	*M*	150	300	500	800	1200	2000	*M*
Both-switch	930	901	853	854	900	941	896	866	820	809	850	913	820	846
	(192)	(245)	(185)	(192)	(199)	(138)		(190)	(189)	(143)	(209)	(206)	(136)	
Error (%)	25	11	14	18	28	28		19	15	15	19	15	8	
Cue-switch only	956	850	796	829	779	940	858	870	750	739	751	748	828	781
	(97)	(141)	(166)	(108)	(86)	(197)		(291)	(156)	(93)	(156)	(116)	(195)	
Error (%)	22	14	14	15	19	23		14	17	20	10	12	11	
No-switch	954	849	813	871	884	916	881	798	765	758	730	777	841	778
	(208)	(166)	(143)	(124)	(92)	(210)		(146)	(124)	(167)	(75)	(97)	(186)	
Error (%)	17	13	14	19	19	21		14	15	14	16	8	12	
Switch cost (minus cue-switch effect)	-26	51	57	25	121	1	38	-4	70	70	99	165	-8	65

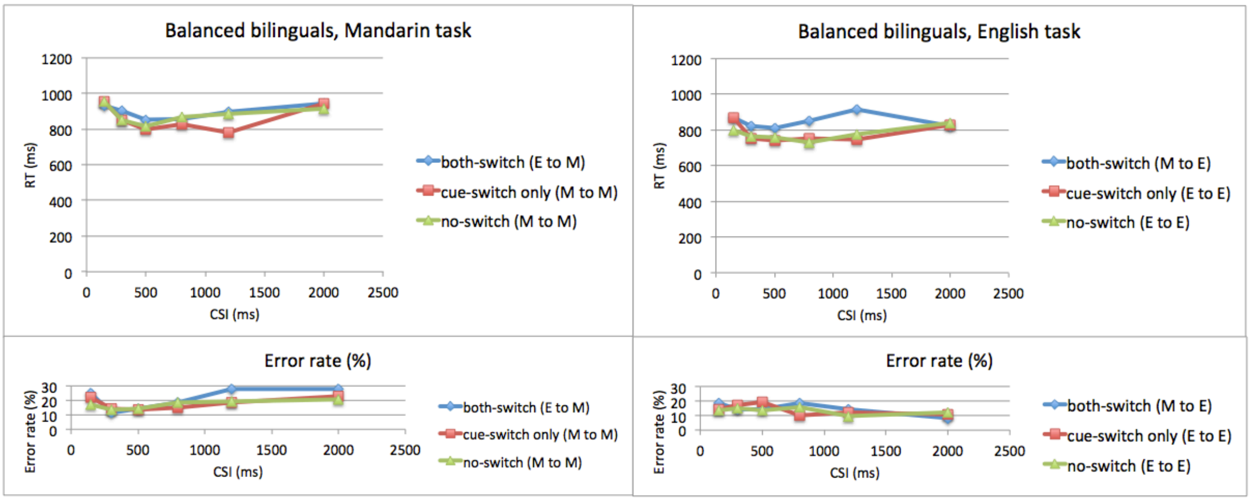
Unbalanced bilingual participants' mean of median RT on the Mandarin task were subjected to a within-subject two-way ANOVA with trial type (both-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) for factors. A main effect of CSI, *F* (5, 55) = 3.69, *p* = .011, was shown, indicating that RTs were reliably higher at a smaller CSI. Only a marginal effect of trial type was found, *F* (1, 11) = 3.78, *p* = .078, showing that when switching into their less dominant language, Mandarin, this group experienced no significant switch costs (Figure 29a).



Figures 29a and 29b: Graphs demonstrating the mean of median reaction time of unbalanced bilinguals when naming pictures in Mandarin (29a, left) and English (29b, right), and the mean of median reaction time when switching into either of these languages. Error rates (proportion of all responses) are shown below each graph.

A within-subject two-way ANOVA with the factors trial type (both-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) was also applied to this group’s RT performance on the English task which involved naming pictures in English no-switch or cue-switch-only trials, or switching from naming in Mandarin to naming in English (both-switch trials). A main effect of trial type, F (1, 11) = 36.81, $p < .0001$, showed that the participants experienced a significant cost for switching into English, their dominant language. Also of interest to this study was whether any support could be found for Logan and Bundesen’s (2003) claim that task switch cost is confounded with cue switches. A within-subject two-way ANOVA with trial type (no-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) as factors was applied to the relevant RT data. The mean of median RT for no-switch trials was compared to the RT for cue-switch-only trials. No main effect was found, F (1, 11) = .32, p = .585, showing that cue-switch-only trials were not significantly different from no-switch trials.

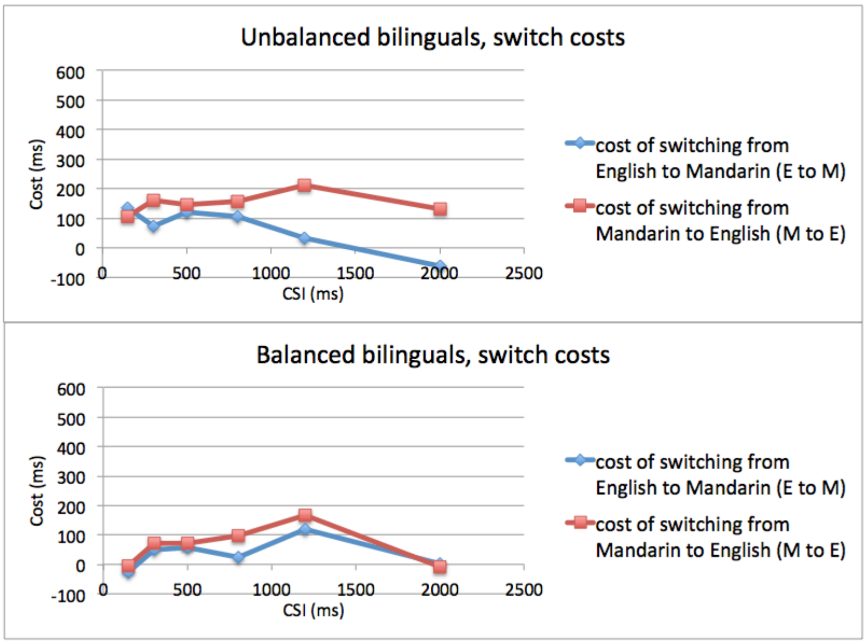
RT performance on both-switch trials and cue-switch-only trials by balanced bilinguals on the Mandarin task was also measured. A within-subject two-way ANOVA with trial type (both-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) as factors revealed a marginally significant effect of trial type, *F* (1, 11) = 3.64, *p* = .083, and of CSI, *F* (5, 55) = 3.64, *p* = .083. This finding mirrors that of the unbalanced bilinguals in the Mandarin task, i.e. no switch cost was also demonstrated by this group of bilinguals when switching into Mandarin. On the other hand, when switching to English this group of balanced bilinguals demonstrated a significantly higher RT, i.e. a switch cost was observed (Figure 30b below). RTs of the English task were subjected to a within-subject two-way ANOVA with the factors trial type (both-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms). This showed a main effect of trial type, *F* (1, 11) = 23.75, *p* < .0001. As above, RTs in no-switch trials were compared with cue-switch-only trials to determine if cue-switches contributed to switch costs. A within-subject two-way ANOVA examining the effect of a cue change using the factors trial type (no-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) did not show any main effects, indicating that switch costs were free of cue effects.



Figures 30a and 30b: Graphs demonstrating the mean of median reaction time of balanced bilinguals when naming pictures in English (30a, left) and Mandarin (30b, right), and the reaction time when switching into either of these languages. Error rates (proportion of all responses) are shown below each graph.

Returning to the two questions posed at the start of this section, the findings of Experiment 3A so far suggest that switch costs can be demonstrated even when cue confounds are partialled out. However, an unexpected finding was that RTs for switching into Mandarin was not significantly different from RTs for continuing to name in Mandarin for *both* unbalanced and balanced bilinguals. In other words no switch cost was found for this task. On the face of it, this would indicate that in answer to the second question – unbalanced and balanced bilinguals do not show different patterns of language switching. Following the standard procedure in language switching studies (e.g., Costa et al., 2006; Meuter & Allport, 1999), we examined the switch cost data of unbalanced and balanced bilinguals for patterns of asymmetry or symmetry. It is also the convention in language switching studies to report patterns of asymmetry or symmetry based on the mean RT, of switch costs of a language versus another language (e.g., Costa & Santesteban, 2004). Since there was a total of six sets of switch costs for each language, one at each CSI, these switch costs were collapsed across the CSI and sorted by language to provide for a set of Mandarin versus English switch costs. As before, we follow Monsell and Mizon (2006) in basing our analyses on participants' median RT.

For this analysis, switch cost data was first prepared. For each group of bilinguals and for each language, cue-switch-only RTs were subtracted from both-switch RTs. This formed four sets of switch cost data, each representing the time taken to switch into one particular language (Mandarin or English) for each bilingual type (balanced or unbalanced). For unbalanced bilinguals, a within-subject two-way ANOVA with factors language task (English, Mandarin) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) was run on their switch cost data. The result showed a significant effect of language task, $F\,(1, 11) = 5.69$, $p = .036$, indicating that unbalanced bilinguals took a significantly longer time to switch into English than they did to switch into Mandarin, thus showing a pattern of asymmetrical costs. No significant interactions between language task and CSI were noted, $F\,(5, 55) = 1.29$, $p = .28$, indicating that switch costs did not decrease as the CSI increased (Figure 31a below). The switch cost data of balanced bilinguals was also analysed. A within-subject two-way ANOVA (language × CSI) showed no main effect of language task, $F\,(1, 11) = .17$, $p = .69$, and no significant interactions, $F\,(1, 11) = .52$, $p = .76$. This result indicated that balanced bilinguals did not switch differently between English and Mandarin, and that the switch costs did not decrease as the CSI increased (Figure 31b). In sum, the switch cost analysis showed that unbalanced and balanced bilinguals did exhibit different language switching behaviour, although both their switch costs did not decrease as the CSI increased.



Figures 31a and 31b: The mean of median reaction time of English and Mandarin switch costs of unbalanced bilinguals (31a, top) and balanced bilinguals (31b, bottom), plotted across the cue-stimulus interval (CSI), when the response-cue interval (RCI) was 160 ms.

Discussion

This experiment was motivated by the need to address the possibility that previously reported language switch effects were simply the result of cue switches rather than a genuine language switch. It used a novel language switch paradigm that aligned itself with recent task switch methods shown to safeguard against such a confound. In particular, it assigned two cues to one task to create a cue-switch-only trial that enabled the partialling out of cue switches from language switches. The experiment was also concerned with switch cost patterns associated with suppression and reconfiguration. To this end, and with the paradigm, it explored (1) whether “true” language switch costs could be demonstrated, (2) if unbalanced bilinguals switched differently from balanced bilinguals, and (3) if language switch costs reduced as the CSI increased.

The results showed that, first, without the confound of a change in cue, switch costs were demonstrated only in the English task for the two groups. Second, and to prediction, unbalanced bilinguals took longer to switch into their dominant language, English, than they did to switch into their less dominant language, Mandarin, while balanced bilinguals took the same time to switch into each of their languages. Third, the switch costs of both unbalanced and balanced bilinguals did not reduce as the CSI increased, indicating a CSI pattern different from that found in task switch studies (Meiran et al., 2000; Monsell & Mizon, 2006). Each of these results is discussed in turn.

The first result showed that a reliable switch effect cost could be demonstrated in the English task, assuring us that methodologically using a picture-naming task in a language switching experiment can yield switch costs without cue change effects. This position differs from Logan and Bundesen (2003), who showed that task switch costs largely reflected the time taken to change cues, but who also had not adopted the measures that were later recommended by Monsell and Mizon (2006) to encourage “true” task switch effects. Therefore, the demonstration of English switch costs not only validates the use of picture-naming stimuli to examine language control, it also supports Monsell and Mizon’s recommendations of using a low probability of switch trials in relation to repeat trials in language switching experiments, as well as using two cues per task to prevent cue confounds.

Demonstrating true English switch costs however does not resolve the debate as to what they might reflect (see Bobb & Wodniecka, 2013 and Monsell, 2003). They could be explained as the time taken to release the suppression applied to an obsolete English task (Allport et al., 1994; Green, 1998), or they could reflect the extra time taken to reconfigure settings in preparation for an upcoming English task (Rogers & Monsell, 1995). The method we used to identify reconfiguration processes was to vary the CSI while keeping the RCI constant. If switch costs reduced as the CSI increased (which they did not), this would lend support to the reconfiguration view. This relates to the third finding and therefore we hold the discussion of the switch cost until CSI effects and switch costs are treated more fully in the latter part of this section.

Having briefly considered what English switch costs might reflect, the absence of a significant switch cost in the Mandarin task is puzzling. Task- and language switch frameworks centre on explaining switch cost phenomena and therefore cannot be applied to this result. Basically, if no significant switch costs are incurred, it is implied that in carrying out a switch into Mandarin, the process of unsuppressing the Mandarin task and then suppressing the English task did not take up significant resources. Or, it is implied that a configured English task set did not require a significant amount of time to be reconfigured into a Mandarin task. Both of these reasons are known to be highly improbable (Monsell, 2003). Although, non-significant switch costs have been reported in two studies where participants were instructed to switch between different stimulus types (Finkbeiner et al., 2006) or univalent stimuli (Allport et al., 1994). However, since the stimulus type in the present experiment was constant and bivalent, these cases do not relate to the present result.

One way to explain the absence of a Mandarin switch cost effect is that the bilinguals were naturally slow to name pictures in Mandarin such that repeating a response in Mandarin was as difficult as switching into Mandarin, giving rise to a situation where no significant costs were incurred. The delay in Mandarin naming may also be due to the short RCI of 160 ms. Under this RCI in a Mandarin cue-switch-only trial, bilinguals are almost instantly faced with another Mandarin cue, just after having completed a Mandarin task on the previous trial. The stress of having to respond in the second language through weak lexical links (Kroll & Stewart, 1994), coupled with the rapid, continued demand to use that language, could have taxed the process of retrieving Mandarin lexical representations through these links. Since a short RCI has been linked to poorer performance due to the influence of the previous trial (Altmann, 2005; Meiran et al., 2000), it could be that after completing a Mandarin task, residual activation from the completed Mandarin task set was carried over to the subsequent Mandarin trial, and interfered with the retrieval process.

This raises the question of why balanced bilinguals, being proficient in Mandarin, too did not show significant Mandarin switch costs. We concede that unless this is an effect of chance, their language background could have subtly affected their Mandarin performance. In their self-reports, participants who had classified themselves as “balanced” indicated that Mandarin was not their first language. These bilinguals used mainly English and some Mandarin in daily communication; this pattern was reversed when they were at home. In all other relevant domains, which included most peer and teacher interactions, and online communication, English was used. This indicated that their language use was domain-specific, and heavily weighted in English. It also means that even though this group of bilinguals were adept at speaking in Mandarin, in all other contexts except at home, they preferred using English. Thus, using a less preferred language in a foreign domain may have had a profound effect on naming in Mandarin. Given that language switch costs are typically no larger than 100 ms (e.g., Christoffels et al., 2007; Costa & Santesteban, 2004), a slight increase in the RT of Mandarin cue-switch-only trials due to the short RCI would have rendered Mandarin switch costs non-significant.

On the basis of Monsell and Mizon’s (2006) task switch design, the RCI of the current experiment had been set at 160 ms. Due to the possibility that the current group of bilinguals may have required more time to resolve task settings associated with irrelevant Mandarin representations persisting from the previous trial, Experiment 3B follows this up by extending the RCI to 900 ms.

The second question asked if unbalanced and balanced bilinguals switched between their languages differently after controlling for cue effects. We found that unbalanced and balanced bilinguals respectively demonstrated patterns of asymmetrical and symmetrical switch costs. That is, unbalanced bilinguals took longer to switch into English than they did to switch into Mandarin, and balanced bilinguals took the same amount of time to switch into Mandarin or English. This is in agreement with predictions of the IC model (Green, 1998) as well as language switching studies showing that language switch cost patterns are dependent on the relative dominance of a bilingual’s two languages (Costa & Santesteban, 2004; Meuter & Allport, 1999). The classic pattern of switch cost asymmetry may be explained as such: unbalanced bilinguals, while speaking in Mandarin, had to suppress English according to how dominant it was so that it would not interfere with a Mandarin response. If the next cue indicated an English task, then English had to be unsuppressed. Overcoming the suppression applied to English required more time, than if Mandarin had been suppressed. Thus, English switch costs were larger than Mandarin switch costs. Accordingly, balanced bilinguals showed equivalent costs for each language.

However, although the predicted switch cost patterns of each group were shown, the absence of a reliable effect of Mandarin switch costs in both bilingual groups is anomalous and weakens the above interpretation. If both groups did not show a switch cost effect for switching into Mandarin, then switch cost patterns are misleading in that significant English switch costs are being compared with non-significant values of Mandarin switch costs. Potentially, the achieved switch cost asymmetry of unbalanced bilinguals and switch cost symmetry of balanced bilinguals are based on lower-than-expected values of Mandarin switch costs, and may show an inaccurate picture of what is believed to reflect bilingual language dominance. We have tentatively suggested that this is an effect of an insufficient RCI which did not allow for the complete resolution of a persisting irrelevant Mandarin representation and pend further discussion until the results of the next experiment are finalized.

The third finding was that as the CSI increased, switch costs did not decrease, leading one to conclude that if task set reconfiguration of a language set occurred during the CSI, it may be experienced differently from reconfiguring a non-language task set. Monsell (2003) accounts for the reduction of switch costs in the following way. If participants do not know about the task before hand, they are not able to engage their cognitive processes in any particular manner. However, once the cue appears indicating for a change in task, participants are able engage their control system and begin taking advantage of the time available to prepare for the new task. It follows that the more time they have to prepare, the less time they will need to switch into the new task. This signature of task set reconfiguration – a reduction in switch cost as the CSI increases – is not evident in the language switch cost patterns obtained for both bilingual groups (Figures 31a and 31b).

The result is supported by other studies that have shown that a longer CSI does not necessarily lead to reduced switch costs (Costa & Santesteban, 2004; Declerck, Philipp, &

Koch, 2013; Philipp et al., 2007). In each of these studies however, the CSI varied on two levels, a short condition and long condition. Our own result differs as we examined switch costs over six CSIs. Specifically, our result shows that switch costs do not vary with the CSI. As this remains a novel finding, in the following Experiment 3B, the same range of CSIs will be retained (160 ms to 2,000 ms) to examine if the irregular pattern of language switch costs holds.

Experiment 3B

Overview

Experiment 3A showed two unprecedented findings.

The first of these was that after controlling for cue effects, bilinguals did not take shorter to repeat a task in Mandarin (following a sequence of two unique cues), than they did to switch from English to Mandarin. This is unusual, given that it has been firmly established in task- and language switch literature that a switch trial always takes longer to perform than a repeat trial (Bobb & Wodniecka, 2013; Kiesel et al., 2010; Monsell, 2003). It was suggested that based on unbalanced bilinguals' weakness in Mandarin, and balanced bilinguals' preference for English, the short RCI of 160 ms may have been too demanding a condition to allow bilinguals to adjust to a language switching situation. More time might have been needed to access one Mandarin representation to the next.

The second finding was that switch costs did not decrease over the CSI. The basis for expecting this pattern in language switching to occur as it does in task switching is that the dominant view in bilingual language production holds that the executive control system which governs non-language tasks similarly acts on language tasks (Green, 1998; Norman & Shallice, 1986). There is evidence that shows that non-language and language tasks behave similarly (Campbell, 2005; Jackson et al., 2001; Meuter & Allport, 1999) and therefore it seems reasonable to extend task set reconfiguration as applied in the task domain, to the language domain. Experiment 3A however showed that the CSI may not be utilized in the manner as it is in task switching.

Experiment 3B was conducted to further explore the above two findings and also took into account the methodological procedures applied in Experiment 3A. These were to control for cue confounds and to set a low probability of switch trials (25%) to repeat trials (75%). It extended the RCI from 160 ms to 900 ms to allow participants sufficient time to resolve the potential need to overcome settings from a previous Mandarin representation, or competition presented by an interfering favoured language system. It fixed the CSI at the same range of values as in Experiment 3A (150, 300, 500, 800, 1,200 and 2,000 ms) to examine whether the irregular switch cost pattern over the range of CSI would be replicated.

The questions Experiment 3B aimed to answer were:

(1) When a longer RCI is introduced, and after controlling for cue switches, is a switch cost demonstrated when switching into the Mandarin task?

(2) Unbalanced bilinguals showed asymmetrical switch costs and balanced bilinguals showed symmetrical switch costs at the shorter RCI. Do they continue to show this expected switch cost pattern at a longer RCI?

(3) Bilinguals did not show a reduction of switch costs in the CSI when RCI was 160 ms. Does this still apply at a longer RCI?

Method

Participants

The same group of 24 students were tested on the same day.

Procedure

The experiment was identical to Experiment 3A except that the RCI was set at 900 ms. Each trial began with a fixation cross in the centre of the screen. A cue appeared after 900 ms and a picture stimulus appeared after a CSI of 150, 300, 500, 800, 1,200, or 2,000 ms. Both cue and stimulus stayed onscreen until a response was made, otherwise a maximum of 4,000 ms would elapse before the screen cleared for the next trial to begin.

	RCI	CSI	No. of trials
Block 1	900	150	64
Block 2	900	300	64
Block 3	900	500	64
Block 4	900	800	64
Block 5	900	1200	64
Block 6	900	2000	64

24 cue-switch only, 24 no-switch, and 16 both-switch trials are pseudorandomly presented over 64 trials in each block

Figure 32: The design of Experiment 3B showing block order, response-cue interval (RCI) and cue-stimulus interval (CSI) values, and the break down of trial types. Half the participants in each bilingual group sat for the experiment beginning with Block 1 and proceeded in ascending order of blocks, and the other half performed in the reverse block order beginning with Block 6.

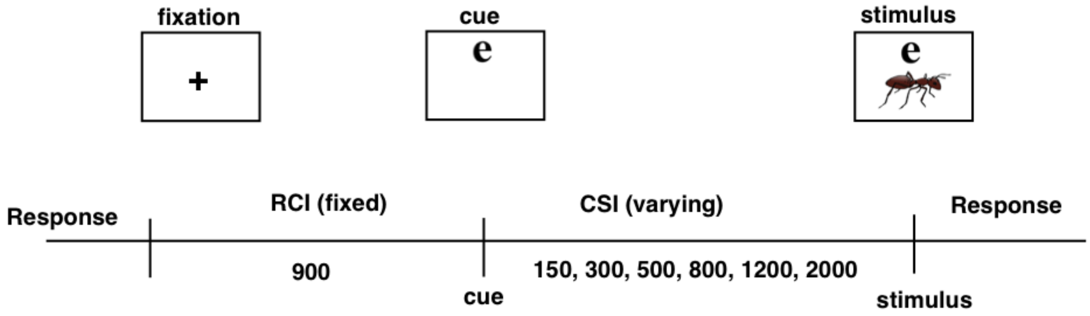


Figure 33: Schematic of a cued English language task in Experiment 3B with numerical values given in milleseconds. The response-cue interval (RCI) was extended from 160 ms in Experiment 3A to 900 ms in the current Experiment 3B to accommodate any residual activity from the previous trial.

Data Analysis and Results

To reiterate the logic advanced in the earlier Data Analysis and Results section, both-switch trials were contrasted with cue-switch-only trials to partial out the influence of a cue change. Since these two types of trials differ only in a change in language, the net result of this comparison is a “pure” language switch. To check for significant time delays caused by cue-processing, cue-switch-only trials were contrasted with no-switch trials. In these two types of trials, only the cue changes. Therefore this contrast yields the time taken to process a cue. This procedure of checking for language switches and cue switches was used in the following planned comparisons using tests of analyses of variance (ANOVA) to examine both-switch and cue-switch-only reaction time (RT). Alpha level was set to .05.

Tables 8a and 8b

Mean of median reaction time (and standard deviations in parentheses) and error rate of unbalanced bilinguals (8a, top) and balanced bilinguals (8b, bottom).

	Mean of median RT of Mandarin Task, *M* (*SD*)							Mean of median RT of English Task, *M* (*SD*)						
CSI (ms)	150	300	500	800	1200	2000	*M*	150	300	500	800	1200	2000	*M*
Both-switch	1049	1123	1033	972	1130	1062	1061	1051	885	1019	1075	932	1016	996
	(179)	(198)	(140)	(180)	(217)	(181)		(213)	(146)	(235)	(166)	(137)	(226)	
Error (%)	22	33	28	22	29	24		9	10	14	18	9	13	
Cue-switch only	1037	923	994	969	1039	1028	998	878	838	862	840	878	865	860
	(245)	(132)	(191)	(208)	(206)	(262)		(102)	(127)	(143)	(126)	(188)	(117)	
Error (%)	22	22	27	27	28	29		8	4	8	6	8	7	
No-switch	1091	1021	1019	1089	1028	1066	1052	869	838	841	806	808	886	841
	(249)	(255)	(304)	(279)	(172)	(233)		(149)	(71)	(137)	(83)	(96)	(119)	
Error (%)	25	26	26	22	21	19		8	3	6	8	8	10	
Switch cost (minus cue-switch effect)	12	200	39	3	91	34	63	173	47	157	235	54	151	136

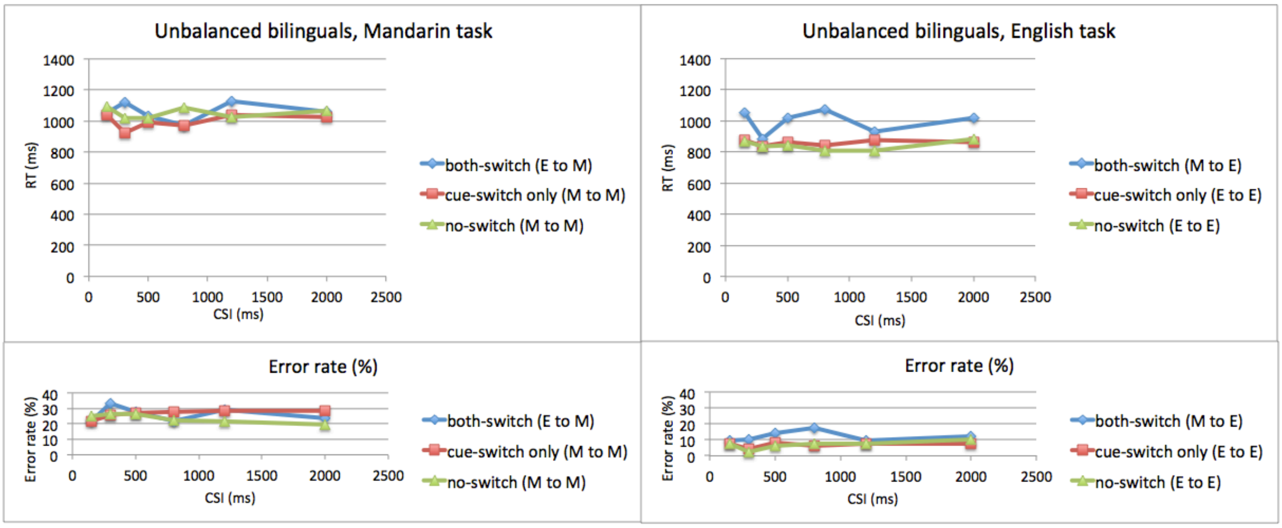
	Mean of median RT of Mandarin Task, *M* (*SD*)							Mean of median RT of English Task, *M* (*SD*)						
CSI (ms)	150	300	500	800	1200	2000	*M*	150	300	500	800	1200	2000	*M*
Both-switch	967	933	871	923	915	924	922	874	816	737	769	833	945	829
	(180)	(208)	(177)	(152)	(190)	(139)		(161)	(181)	(95)	(165)	(185)	(308)	
Error (%)	23	19	19	25	22	23		14	15	15	14	15	18	
Cue-switch only	845	882	823	818	835	913	853	753	759	773	762	760	832	773
	(110)	(193)	(130)	(142)	(177)	(185)		(96)	(109)	(128)	(128)	(93)	(137)	
Error (%)	21	13	16	16	20	13		9	9	10	11	10	10	
No-switch	870	815	837	841	884	897	857	745	750	755	764	800	796	768
	(150)	(107)	(115)	(150)	(156)	(192)		(132)	(120)	(138)	(112)	(157)	(165)	
Error (%)	17	13	11	15	15	17		14	14	12	10	13	18	
Switch cost (minus cue-switch effect)	122	51	48	105	80	11	70	121	57	-36	7	73	113	56

Data preparation followed the exact procedures as in Experiment 3A. The data were first coded, and then responses were checked. Errors and the trials following those errors were excluded from the analyses of response latencies. We followed the practice of Monsell and Mizon (2006), and trimmed from the data reaction time (RT) greater than two seconds. This procedure of excluding errors and trimming the RTs removed 16% of all trials. We based RT analyses on the medians of correct RT of each participant. The mean of median reaction time for each CSI for each group and the mean percentage of errors at each level of CSI is shown in tables 8a and 8b. A mixed three-way ANOVA (group × trial type × language task) on error data showed that unbalanced bilinguals made more errors than balanced bilinguals, *F* (1, 22) = 4.58, *p* = .031. More errors were made in Mandarin than English, *F* (1, 22) = 214.23, *p*

< .0001, and no-switch trials were less error-prone than the other two trial types, *F* (1, 22) = 17.18, *p* < .0001. There was an interaction between language task and group, *F* (1, 22) = 68.44, *p* < .0001, as unbalanced bilinguals made significantly more errors than balanced bilinguals when the task was in Mandarin than when it was in English.

Experiment 3B aimed to address the impact of longer RCI on the switching patterns of balanced and unbalanced bilinguals. It followed up from the findings of Experiment 3A, the first of which was to see if Mandarin switch costs could be demonstrated. It also questioned if unbalanced and balanced bilinguals would continue to show their expected switch cost asymmetry and symmetry, and if these costs would decrease as the CSI increased. Tables 8a and 8b above show the mean of median RT for each language at each CSI, for unbalanced and balanced bilinguals.

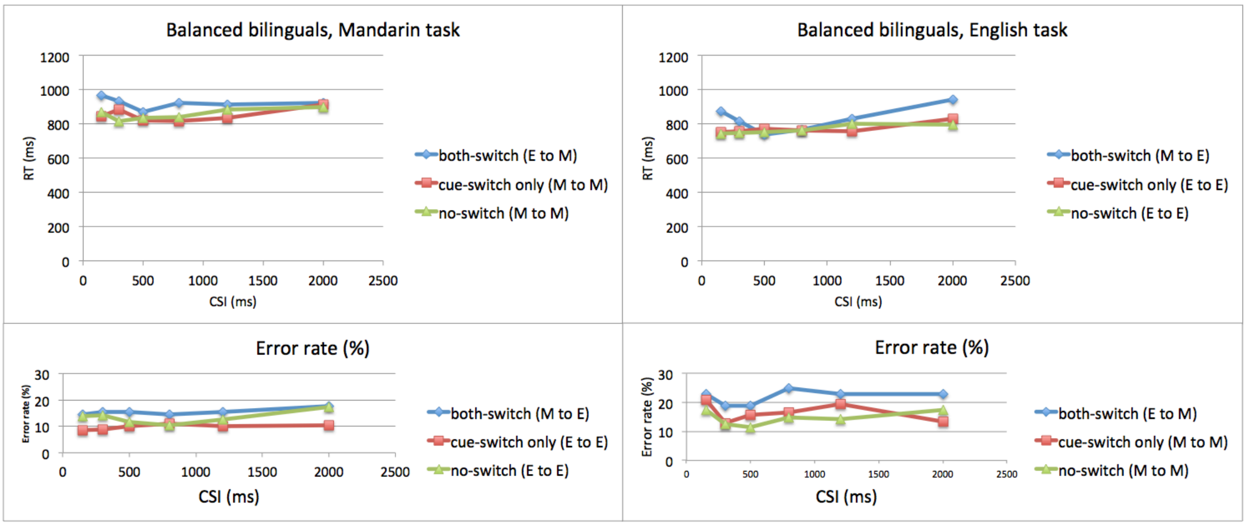
Unbalanced bilinguals' RTs of the Mandarin task were assessed for a switch cost effect. A within-subject two-way ANOVA with the variables trial type (both-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) showed a main effect of trial type, *F* (1, 11) = 7.61, *p* = .019, demonstrating that unbalanced bilinguals showed a cost for switching into Mandarin, and no significant interactions. Mandarin cue-switch-only RTs and Mandarin no-switch RTs for this group were next submitted to a within-subject two-way ANOVA (trial type × CSI) to check for contributions of a change in cue. The result showed a main effect of trial type, *F* (1, 11) = 5.32, *p* = .042, indicating a significant difference between cue-switch-only trials and no-switch trials. Figure 34b reveals this difference to be atypical: unbalanced bilinguals were *faster* to respond to Mandarin cue-switch-only trials than Mandarin no-switch trials, indicating that repeating a response in Mandarin after a change in cue took *less* time to perform than when the Mandarin cue remained the same.



Figures 34a and 34b: Graphs demonstrating the mean of median reaction time of unbalanced bilinguals when naming pictures in Mandarin (34a, left) and English (34b, right), and the mean of median reaction time when switching into either of these languages. Error rates (proportion of all responses) are shown below each graph.

Unbalanced bilinguals' RTs of the English task were also subjected to a within-subject two-way ANOVA with the factors trial type (both-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms). A main effect of trial type, *F* (1, 11) = 20.11, *p* < .001, indicated that cue switches did not affect English repetitions, hence unbalanced bilinguals showed a switch cost for switching into English. No other main effects or interactions were found (all *ps* > .05). A within-subject two-way ANOVA with the factors trial type (cue-switch-only, no switch) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) did not reveal any main effects or interactions (all *ps* > .05), indicating that the unusual cue-switch facilitation effect was confined to the Mandarin task.

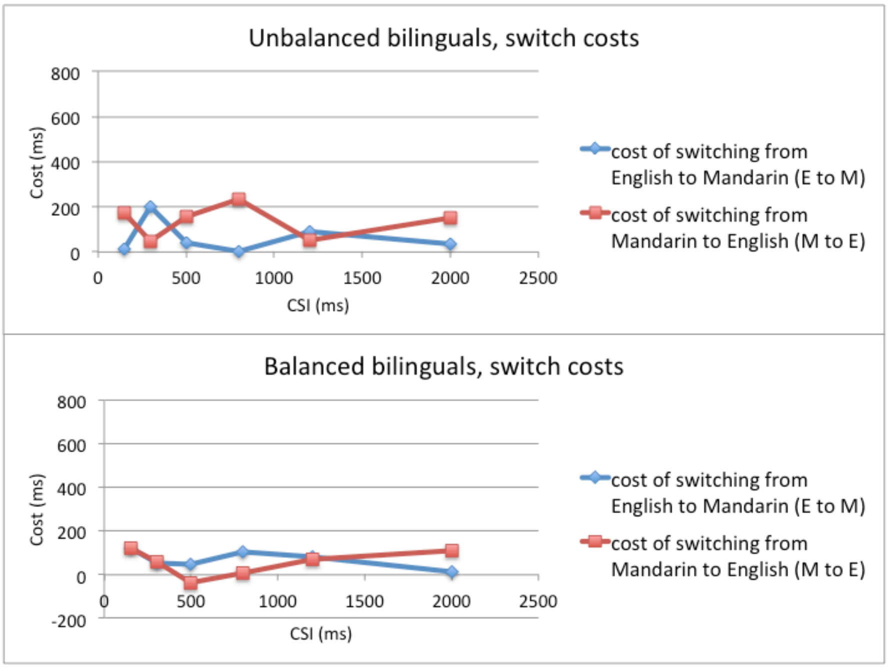
Balanced bilinguals' RTs of the Mandarin task were next assessed for a switch cost effect. A within-subject ANOVA with the factors trial type (both-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) on these RTs revealed a significant effect of trial type, *F* (1, 11) = 10.06, *p* =.009, showing that the impact of a long RCI brought out Mandarin switch costs. A within-subject two-way ANOVA with the factors trial type (cue-switch-only, no-switch) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) showed that balanced bilinguals responded in Mandarin without being significantly affected by a cue change, *F* (1, 11) = .069, *p* = .80. Balanced bilinguals' RTs of the English task were also assessed for switch cost effects. The within-subject ANOVA for this took for factors trial type (both-switch, cue-switch-only) and CSI (150, 300, 500, 800, 1,200, 2,000 ms), and showed a main effect of trial type, *F* (1, 11) = 5.89, *p* = .034, demonstrating expected English switch costs. A marginal main effect of CSI, *F* (5, 55) = 3.14, *p* = .049, showed that English both-switch RTs were higher than English cue-switch-only RTs at a long CSI (see Figure 35a). A within-subject ANOVA with the factors trial type (cue-switch-only, no-switch) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) tested for possible influences of a change in English cues, but no main effects or significant interactions were found (all *ps* > .05), indicating that English cue-switch-only RTs were not significantly different from English no-switch RTs.



Figures 35a and 35b: Graphs demonstrating the mean of median reaction time of balanced bilinguals when naming pictures in Mandarin (35a, left) and English (35b, right), and the mean of median reaction time when switching into either of these languages. Error rates (proportion of all responses) are shown below each graph.

Thus far, switch cost analyses show that by increasing the RCI from 160 in the previous experiment to 900 ms in the present experiment, Mandarin switch costs could be demonstrated in balanced and unbalanced bilinguals. Analyses also uncovered an unanticipated behaviour by unbalanced bilinguals – they were *faster* to repeat a response in Mandarin following a sequence of two unique cues than when it followed a sequence of identical cues.

Following up on the expected switch cost asymmetry and symmetry that unbalanced and balanced bilinguals showed in Experiment 3A, further analyses were carried out to see if these patterns were replicated. These analyses also served to examine if these switch costs would decrease as the CSI increased. Switch cost data was prepared as in Experiment 3A by subtracting cue-switch-only RTs from both-switch RTs for each language and each group of bilinguals. The within-subject two-way ANOVA with the factors language (Mandarin, English) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) on switch cost RTs for unbalanced bilinguals showed that Mandarin and English switch costs were not significantly different, *F* (1, 11) = 3.65, *p* = .082. This was unexpected considering the seemingly disparate trends of unbalanced bilinguals' switch costs shown in Figure 36a. A within-subject two-way ANOVA with the factors language (Mandarin, English) and CSI (150, 300, 500, 800, 1,200, 2,000 ms) on the switch cost RTs for balanced bilinguals did not show a main effect of language, *F* (1, 11) = 1.31, *p* = .28, indicating that Mandarin and English switch costs were not significantly different. In each of these analyses, there were no reliable language by CSI interactions (all *p*s > .05), showing that unbalanced and balanced bilinguals' switch costs did not decrease as the CSI increased.



Figures 36a and 36b: Graphs showing the mean of median reaction time of unbalanced bilinguals (36a, top) and balanced bilinguals (36b, bottom) when naming a picture correctly in Mandarin followed by naming another picture correctly in English (blue line) and naming a picture correctly in English followed by naming another picture correctly in Mandarin (red line).

Discussion

The findings of Experiment 3A suggested that participants experienced difficulty in performing Mandarin trials in succession because of a short RCI. Related to this finding were the expected patterns of asymmetry and symmetry respectively seen in unbalanced and balanced bilinguals that could be explained by the IC model (Green, 1998), but which had to be carefully interpreted because of the absence of Mandarin switch costs in both groups. The findings also suggested that the irregular pattern of switch costs at a range of CSIs was indicative of processing differences between language switching and task switching. Following these results of Experiment 3A, Experiment 3B was conducted to see if, at a longer RCI, (1) switch costs could be demonstrated for switching into the Mandarin task, (2) unbalanced and balanced bilinguals would show their expected switch costs patterns as they did in Experiment 3A, and (3) the irregular pattern of language switch costs over an increasing CSI persisted.

There were three main results. First, both bilingual groups showed Mandarin switch costs, demonstrating a role that the RCI played in influencing switch cost patterns, as well as reaffirming the picture-naming methodology as a viable method for studying language switching. Second, balanced bilinguals showed expected symmetrical switch costs. Unexpectedly though, unbalanced bilinguals too showed symmetrical switch costs. Third, the irregular switch cost patterns across a range of CSIs was replicated, giving support to the view that CSI processes as understood in the task domain may be different when applied to the language domain. An unusual finding was that unbalanced bilinguals found it harder to perform a repeated Mandarin task if it followed from a sequence of two identical Mandarin cues compared with two unique Mandarin cues. These results are discussed below.

The first result showed that a longer RCI was sufficient to demonstrate significant Mandarin switch costs in unbalanced and balanced bilinguals. This favours the suggestion put forward in Experiment 3A. This was that if a language was weak, then changing task settings configured to a particular representation would need time to be resolved, if a subsequent representation in the same language was to be carried out optimally. A tentative piece of support for this interpretation is the average decrease (by 34 ms) in unbalanced bilinguals' mean of median Mandarin cue-switch-only RT in the present experiment compared with the previous. The significance of this is yet to be tested. A more viable approach would be to examine how unbalanced bilinguals carry out Mandarin cue-switch-only trials as the RCI increases. This is explored in Experiment 4.

The second result showed that balanced bilinguals did not take different amounts of time to switch between English and Mandarin, indicating a symmetrical pattern of switch costs. However, unbalanced bilinguals showed the same pattern, implying that they too did not switch differently between each language. This is at variance with the expectation that they show switch cost magnitudes inverse to the proficiency of each language, that is, smaller Mandarin than English switch costs. There is at least one study that has reported a symmetrical switch cost effect in unbalanced bilinguals (Christoffels et al., 2007). The experimental aspect that sets this study apart from other studies in the language switching field is its RCI length. Most studies employ RCIs in the range of 0 to 1,500 ms (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999) while Christoffels et al. fixed their RCI at 1,800 to 2,000 ms, and had found a symmetrical switch cost effect in their unbalanced bilingual sample. This suggests that RCI duration may influence unbalanced bilinguals' switch cost behaviour. Although the present experiment RCI of 900 ms is not long compared with 1,800 or 2,000 ms, considering that our participants had completed Experiment 3A (RCI = 160 ms) prior to performing the present experiment, the pre-exposure to a shorter RCI could plausibly increase their awareness of a longer RCI in the present experiment, and thus encouraged behaviour associated with a long RCI. In Experiment 4, we explore switch cost behaviour over an increasing RCI.

The third result confirmed Experiment 3A's finding of an irregular pattern of switch costs over the CSI. This suggests that potential preparation processes in the CSI may be modulated by strategic variables. Specifically, bilinguals might have adopted a strategy of retrieving a picture's name only after it appeared, instead of actively preparing for the task after the cue appeared. Since they were only reacting after the onset of the stimulus, the switch cost pattern that resulted was one that could possibly reflect their subjective rates of picture name retrieval, which would be understandably irregular. We leave this discussion to the general discussion section.

A final result that remains to be explained is the finding that unbalanced bilinguals were significantly quicker to repeat a Mandarin task when it followed a sequence of two unique cues, than when it followed a sequence of two identical cues. To recap, the purpose of mapping two cues to one task was so that the effect of cue processing could be assessed. Presently, it appears that processing a cue has the counterintuitive effect of lowering, rather than increasing, RT in Mandarin tasks for unbalanced bilinguals. The cause of this is not clear. Since this effect has not been seen in other studies, and considering that its level of significance is not strong ($p = .042$), we hesitate to lend too much importance to the result. If however we are to reconcile the data, this behaviour could possibly reflect the suppression of a Mandarin task set on a previous trial, to the extent that the cue was also suppressed. If the same cue appeared in the following trial, its representation would have to be unsuppressed and re-processed, taking more time than if a different Mandarin cue had appeared. The absence of this behaviour in Experiment 3A suggests that a short RCI was not sufficient for suppression of the Mandarin task set to be completed.

Given the uncertainty of the symmetry or asymmetry of unbalanced bilinguals' switch costs at a long and short RCI, and the potential that these patterns might reveal how activity from a previous trial – task set dissipation – influenced an ongoing trial, Experiment 4 studied the switch cost patterns of unbalanced bilinguals at a range of RCIs.

CHAPTER 8 – EXPERIMENT 4

Overview

Experiments 3A and 3B showed that in addition to what happens during the cue-stimulus-interval (CSI), the response-cue-interval (RCI) is important in that it can potentially tell us about how unbalanced and balanced bilinguals switch to each of their languages. Thus far, this thesis has shown that

(i) it is important for researchers studying bilinguals to take into account cue-switching confounds, especially for different kinds of bilinguals.

(ii) the RCI is potentially useful for unpacking the nature of language switching in bilinguals.

Our own results show that it is not a straightforward finding.

Experiment 3A showed that when the RCI was short (160 ms) unbalanced English-Mandarin bilinguals did not show Mandarin switch costs. We suggested that in using Mandarin from one trial to the next, unbalanced bilinguals might experience interference persisting from the previous Mandarin trial. This inflated the reaction time (RT) of Mandarin cue-switch-only trials to the point where they were no different to Mandarin both switch trials. As a result, no effect of switching into Mandarin was shown. By extending the RCI to 900 ms in Experiment 3B, unbalanced bilinguals showed a cost for switching into Mandarin. Based on this result, we predicted that unbalanced bilinguals would not show Mandarin switch costs at a short RCI, but that this effect would emerge at a long RCI. Balanced bilinguals were expected to show switch costs for switching into Mandarin and English, whether the RCI was short or long.

Experiment 3A also showed that when the RCI was short (160 ms), unbalanced English-Mandarin bilinguals showed overall switch cost patterns of asymmetry. On the other hand, Experiment 3B showed that when the RCI was long (900 ms) the same unbalanced bilinguals showed patterns of symmetry. This suggests that the duration of the RCI might influence unbalanced bilinguals' switch cost behaviour such that at a long RCI, they were able to switch as balanced bilinguals do, and showed overall symmetrical switch costs. We predicted that unbalanced bilinguals would show asymmetrical switch costs at a short RCI, and symmetrical switch costs at a long RCI. Balanced bilinguals were expected to show symmetrical switch costs regardless of RCI duration.

Finally, Experiment 3B confirmed Experiment 3A's finding that the pattern of language switch costs was irregular over a range of CSIs. This implied that the theory of task set reconfiguration (Rogers & Monsell, 1995) could not account fully for language switch costs. In the preceding paragraphs, we have indicated that the RCI may play an important role in language switching. If this is the case, then language switch costs could potentially be accounted for by task set inertia theory (Allport et al., 1994). Task set inertia theory states that the stronger one is at a task, the more difficult it will be to suppress that task when a change to another task is needed, especially when the cue for that change appears quickly in relation to the last response (Allport et al., 1994). Furthermore, by prolonging the duration immediately after completing a task, the completed task has been shown to dissipate and interfere less with that next task to be done (Meiran et al., 2000). As the level of interference of a completed task from the previous trial decreases, performance of the current task improves. Therefore, task set inertia proposes that the dissipation of a task set – indexed by the reduction of switch costs as the RCI increases – is responsible for the switch cost. If task set inertia was responsible for language switch costs, then switch costs would decrease as the RCI increased.

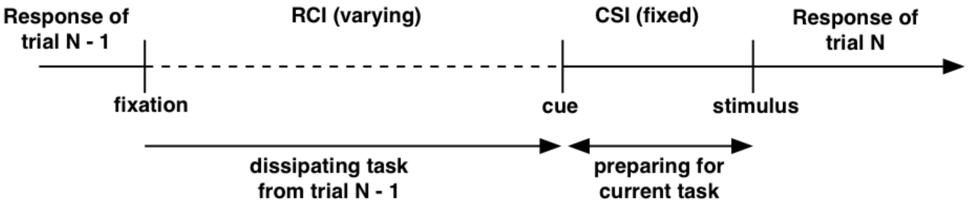


Figure 37: The language switching experimental paradigm used to examine processes in the response-cue interval (RCI). As the duration of the RCI lengthens, activation from trial N-1 dissipates (Allport et al., 1994). This activity is distinct from task set reconfiguration (Rogers & Monsell, 1995) exercised in the cue-stimulus interval (CSI).

Therefore, the reason for conducting Experiment 4 was to examine the RCI more closely given its potential in uncovering possible novel switching behaviour in different types of bilinguals. With this aim, it explored three things. The first was to examine if, when the RCI varied, unbalanced bilinguals would show Mandarin switch costs only when the RCI was long. The second was to see if, when the RCI varied, unbalanced bilinguals would show different patterns of switch cost asymmetry or symmetry. Finally, the third aim was to examine if switch costs would decrease as the RCI increased. Cue confounds were taken into account.

The specific questions this experiment asked were:

1. Do unbalanced bilinguals Mandarin switch costs emerge only at a long RCI?
2. Do unbalanced bilinguals show asymmetrical switch costs at a short RCI but symmetrical switch costs at a long RCI?
3. Do unbalanced and balanced bilinguals switch costs reduce as the RCI increases?

Method

The experiment was the same as Experiment 3A except that the RCI and CSI values were reversed. Six values of the RCI, 150, 300, 500, 800, 1,200 and 2,000 ms were mapped to a fixed CSI. The CSI was held constant to limit the contributions of preparation, but with sufficient time believed to allow cue encoding to be completed (Koch, 2001). All procedures followed that in Experiment 3A.

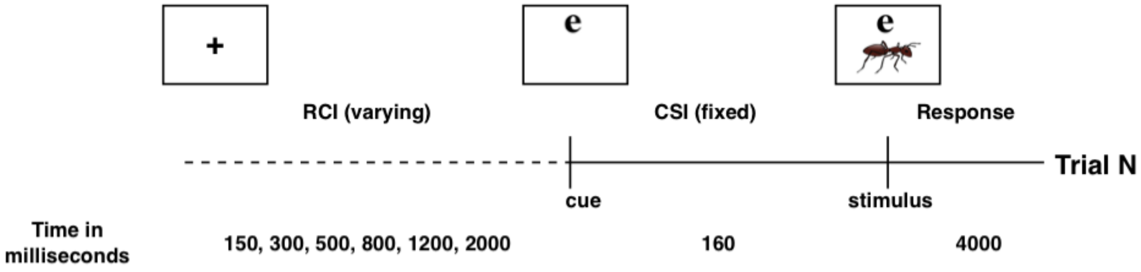


Figure 38: Schematic of a cued English language task in Experiment 4.

	RCI	CSI	No. of trials
Block 1	150	160	64
Block 2	300	160	64
Block 3	500	160	64
Block 4	800	160	64
Block 5	1200	160	64
Block 6	2000	160	64

24 cue-switch only, 24 no-switch, and 16 both-switch trials are pseudorandomly presented over 64 trials in each block

Figure 39: The design of Experiment 4 showing block order, response-cue interval (RCI), and cue-stimulus interval (CSI) values, and the break down of trial types. Half the participants in each bilingual group sat for the experiment beginning with Block 1 and proceeded in ascending order of blocks, and the other half performed in the reverse block order beginning with Block 6.

Participants

A separate group of 24 English-Mandarin bilinguals from the National University of Singapore was recruited following procedures described in Experiment 3A. The formal procedure for obtaining consent and study approval was observed, and a proficiency assessment using the LEAP-Q (Marian et al., 2007) was administered. Half of the participants formed an unbalanced bilingual group (n = 12, mean age = 22.31, *SD* = 1.09 years, range 21-24 years), and the other half a balanced bilingual group (n = 12, mean age = 22.22, *SD* = 1.09 years, range 21-24 years). All the bilinguals in this group were similar to those in the previous experiment in that they were Singaporean and went through the same educational system: they were exposed to English and Mandarin from 0 to 5 years, and learned these languages in school when they were 7. English was used in all classes except for Mandarin lessons. This stayed the same throughout their primary, secondary, and post-secondary school years, until they enrolled into university and formal instruction stopped. The medium of instruction at the university was English. The main difference between the unbalanced and balanced bilingual group was that balanced bilinguals reported speaking Mandarin, or a mix of Mandarin and English at home, while unbalanced bilinguals spoke only English at home.

Tables 8a and 8b

The language history and proficiency characteristics of balanced bilinguals (table 8a, top) and unbalanced bilinguals (table 8b, bottom) in Experiment 4 (see Appendix E).

Balanced Bilinguals

Language history measures	*M*	*SD*	Range
Age in years	22.22	1.09	21-24
Age of L2 acquisition in years	3.08	1.56	0-5
Percentage of daily exposure to L2 (0 = none, 100 = always)	22.17	4.39	15-30
Self-rated L2 speaking proficiency (0 = none, 10 = perfect)	7.83	0.83	7-9
Self-rated L2 reading proficiency (0 = none, 10 = perfect)	7.25	0.45	7-8

Unbalanced Bilinguals

Language history measures	*M*	*SD*	Range
Age in years	22.31	1.09	21-24
Age of L2 acquisition in years	3.92	0.67	3-5
Percentage of daily exposure to L2 (0 = none, 100 = always)	15.67	3.87	11-23
Self-rated L2 speaking proficiency (0 = none, 10 = perfect)	4.75	1.06	3-6
Self-rated L2 reading proficiency (0 = none, 10 = perfect)	3.67	1.61	0-5

As before, we followed Kaushanskaya and Marian's (2009) ratings of high proficiency bilinguals in their study. Therefore, we used as a cut-off the age for learning L2 at 5 years, exposure to L2 daily for at least 12%, a rating of speaking and reading proficiency at 7 or greater out of a scale of 10 to indicate balanced bilingualism.

Data Analysis and Results

Data preparation took the same steps listed in Experiments 3A and 3B. Briefly stated here again for ease of reference, the data were first coded and wrong responses were identified as errors. These errors, along with the next trial with a correct response, were excluded from the analysis. Following the procedure carried out by Monsell and Mizon (2006), the mean of medians of correct RT of each participant were collated. RTs above 2 seconds were identified as outliers and trimmed from the data. Altogether, 16.5% of trials were removed. Alpha level was set to .05. The mean of median RT for each RCI for each group and the mean percentage of errors at each level of RCI are shown in Tables 9a and 9b.

Tables 9a and 9b

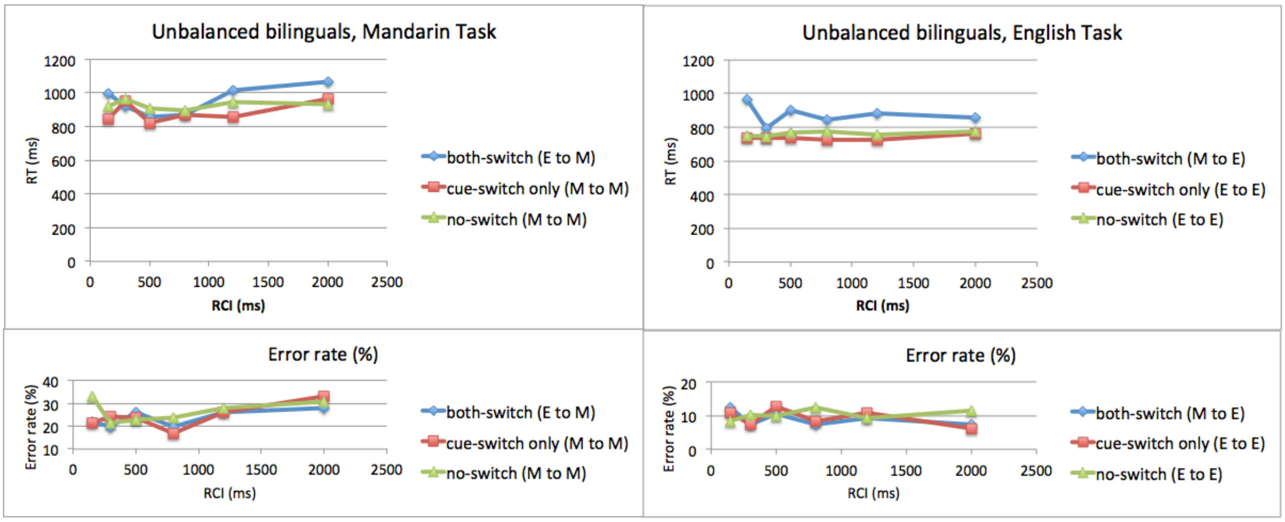
Mean of median reaction time (M) and mean percentage error as a function of response-cue interval (RCI) of unbalanced bilinguals (top) and balanced bilinguals (bottom). Standard deviations (SD) of reaction time are in parenthesis.

	Mean of median RT of Mandarin Task, *M* (*SD*)							Mean of median RT of English Task, *M* (*SD*)						
RCI (ms)	150	300	500	800	1200	2000	*M*	150	300	500	800	1200	2000	*M*
Both-switch	982	916	844	867	1001	1076	947	945	779	911	829	871	842	862
	(240)	(200)	(101)	(161)	(224)	(188)		(238)	(94)	(164)	(187)	(213)	(178)	
Error (%)	22	20	26	20	26	28		13	7	10	7	9	7	
Cue-switch only	841	941	827	875	865	972	886	735	726	728	725	721	759	732
	(155)	(213)	(111)	(174)	(204)	(267)		(96)	(68)	(90)	(129)	(76)	(132)	
Error (%)	21	24	24	17	26	33		11	7	13	8	11	6	
No-switch	907	956	900	895	942	931	921	747	737	753	774	747	765	753
	(171)	(239)	(111)	(152)	(201)	(198)		(96)	(128)	(180)	(134)	(118)	(149)	
Error (%)	33	21	23	24	28	31		8	10	10	12	9	11	
Switch cost (minus cue-switch effect)	141	-25	17	-8	136	104	61	210	53	183	104	150	83	131

	Mean of median RT of Mandarin Task, *M* (*SD*)							Mean of median RT of English Task, *M* (*SD*)						
RCI (ms)	150	300	500	800	1200	2000	*M*	150	300	500	800	1200	2000	*M*
Both-switch	982	916	991	981	1050	894	969	850	883	881	864	883	846	867
	(162)	(210)	(319)	(198)	(219)	(140)		(131)	(158)	(181)	(154)	(95)	(113)	
Error (%)	21	17	18	22	18	19		20	14	16	10	9	17	
Cue-switch only	856	866	819	837	883	878	857	762	737	744	760	782	795	763
	(154)	(175)	(91)	(106)	(131)	(193)		(133)	(96)	(66)	(88)	(89)	(56)	
Error (%)	25	15	16	18	27	19		10	14	10	8	14	10	
No-switch	948	806	831	852	849	879	860	784	727	770	743	736	827	765
	(259)	(131)	(132)	(97)	(144)	(146)		(79)	(79)	(84)	(111)	(93)	(94)	
Error (%)	25	23	27	19	20	26		14	7	11	12	14	12	
Switch cost (minus cue-switch effect)	126	50	172	144	167	16	113	88	146	137	104	101	51	105

A mixed three-way ANOVA (group × trial type × language task) on error data showed no group differences, $F(1, 22) = 1.44$, $p = .24$. More errors were made in Mandarin than in English, $F(1, 22) = 197.8$, $p < .0001$, and no other main effects were noted. There was a language task by group interaction, $F(1, 22) = 9.23$, $p = .006$, because unbalanced bilinguals made more errors in Mandarin than balanced bilinguals but they made fewer errors in English than balanced bilinguals. The interaction among the variables trial type, language group, and trial type was not significant ($F < 1$).

To examine if Mandarin switch costs of unbalanced bilinguals were significantly different over a range of RCI, we followed Allport et al's (1994) method of analyzing RTs of switch and repeat trials over a sequence of blocks. The researchers first performed an overall analysis on the sequence of blocks. Based on graph data showing higher switch costs in the initial blocks compared with the latter blocks, they then separately analysed the initial and latter block. We applied this method to unbalanced bilinguals' Mandarin task performance and kept to the practice of using the mean of median RT. First, we analyzed unbalanced bilinguals' performance across the range of RCI. A within-subject two-way ANOVA with the factors trial type (both-switch, cue-switch-only) and RCI (150, 300, 500, 800, 1,200, 2,000 ms) showed a main effect of trial type, *F* (1, 11) = 5.34, *p* = .041, and RCI, *F* (5, 55) = 3.95, *p* = .012. There were no interactions (*p* > .05). A within-subject two-way ANOVA with the factors trial type (cue-switch-only, no-switch) and RCI (150, 300, 500, 800, 1200, 2000) did not show any main effects. Thus, Mandarin both-switch trials did not contain effects of cue changes. Next, we reviewed the graph data for unbalanced bilinguals' Mandarin task performance (Figure 40a). The mean of median Mandarin cue-switch-only RT appear to diverge when the RCI is 800 ms. Therefore, we took as our "short RCI range", the RCI from 150 to 800 ms, and the "long RCI range", the RCI from 1,200 to 2,000 ms.

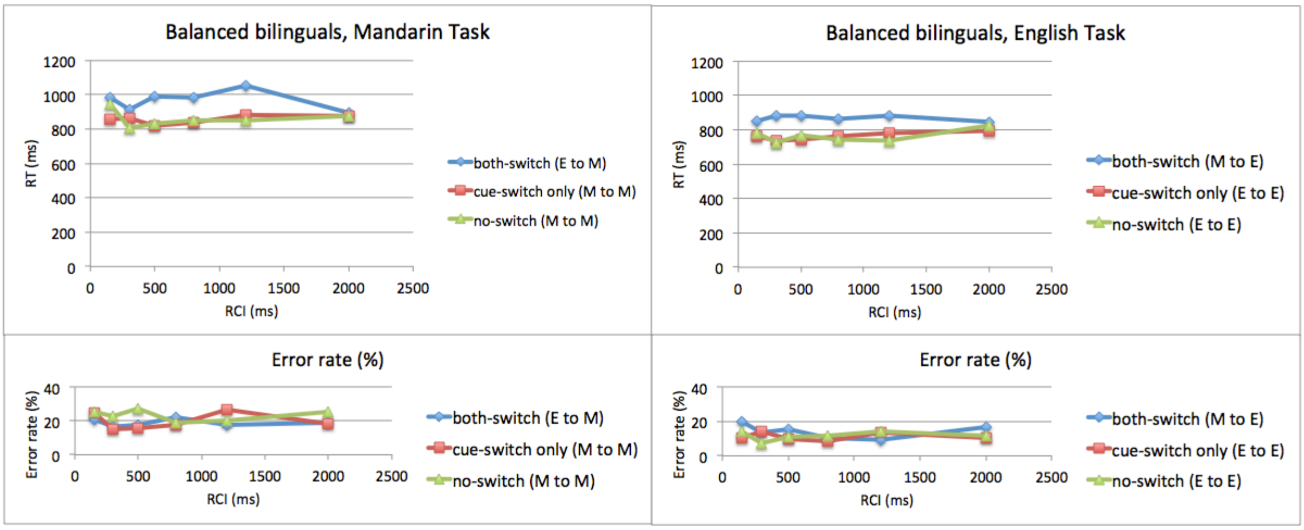


Figures 40a and 40b: Graphs demonstrating the mean of median reaction time of unbalanced bilinguals when naming pictures in Mandarin (40a, left) and English (40b, right), and the mean of median reaction time when switching into either of these languages. Error rates (proportion of all responses) are shown below each graph.

Earlier experiments had suggested that unbalanced bilinguals showed Mandarin switch costs only at a long RCI. To examine unbalanced bilinguals' Mandarin switch costs at the long RCI in the present experiment, we submitted the RTs of the Mandarin task to a within-subject two-way ANOVA with the factors trial type (both-switch, cue-switch-only) and RCI (1,200, 2,000 ms). This showed a main effect of trial type, *F* (1, 11) = 6.51, *p* = .027, indicating a switch cost effect for the Mandarin task at the long RCI range. No interactions were noted. A within-subject two-way ANOVA with the factors trial type (cue-switch-only, no switch) and RCI (1,200 and 2,000 ms) showed that Mandarin switch costs was not confounded with cue switches, *F* (1, 11) = .20, *p* = .66. Next, we analysed unbalanced bilinguals' Mandarin switch costs at the short RCI. A within-subject two-way ANOVA with the factors trial type (both-switch, cue-switch-only) and RCI (150, 300, 500, 800 ms) showed that Mandarin both-switch trials were not differently performed from cue-switch-only trials, *F* (1, 11) = 1.42, *p* = .26. A within-subject two-way ANOVA with the factors trial type (cue-switch-only, no switch) and RCI (150, 300, 500, 800 ms) showed marginal cue switch effects, *F* (1, 11) = 4.11, *p* = .067. There was no interaction between the two variables.

Unbalanced bilinguals' RTs of the English task were next analyzed. A within-subject two-way ANOVA with the factors trial type (both switch, cue-switch-only) and RCI (150, 300, 500, 800, 1,200, 2,000 ms) showed a main effect of trial type, *F* (1, 11) = 23.05, *p* = .001, because unbalanced bilinguals incurred a cost for switching into English. A within-subject two-way ANOVA with the factors trial type (cue-switch-only, no switch) and RCI (150, 300, 500, 800, 1,200, 2,000 ms) did not show significant differences between cue-switch-only and no switch trials, *F* (1, 11) = 1.51, *p* = .25. No interactions were noted in each of these ANOVAs.

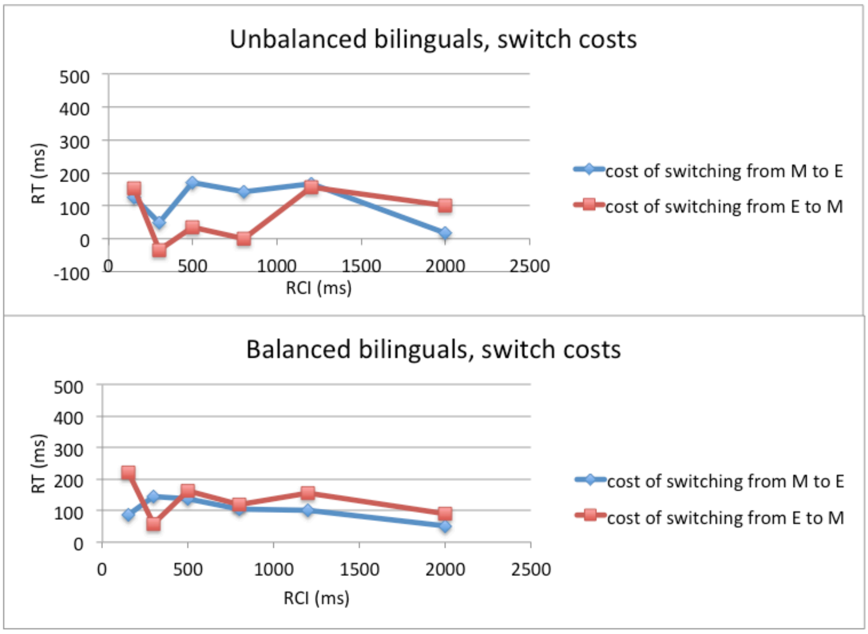
For balanced bilinguals, a within-subject two-way ANOVA with the factors trial type (both switch, cue-switch-only) and RCI (150, 300, 500, 800, 1,200, 2,000 ms) showed they incurred a significant cost for switching into Mandarin, *F* (1, 11) = 13.74, *p* = .003, and a marginal effect of RCI, *F* (1, 11) = .78, *p* = .07. The within-subject two-way ANOVA with the factors trial type (cue-switch-only, no switch) and RCI (150, 300, 500, 800, 1,200, 2,000 ms) did not show any main effect of cue switching, *F* (1, 11) = .08, *p* = .80. The RTs of the English task for this group were submitted to a within-subject two-way ANOVA with the factors trial type (both switch, cue-switch-only) and RCI (150, 300, 500, 800, 1,200, 2,000 ms). This showed a main effect of trial type, *F* (1, 11) = 12.19, *p* = .005, indicating a cost for switching into English. The within-subject two-way ANOVA with the factors trial type (cue-switch-only, no switch) and RCI (150, 300, 500, 800, 1,200, 2,000 ms) applied to the RTs of the English task showed that cue-switch-only and no switch trials were not performed differently, *F* (1, 11) = 1.51, *p* = .25. Balanced bilinguals' data is shown in Figures 41a and 41b.



Figures 41a and 41b: Graphs demonstrating the mean of median reaction time of balanced bilinguals when naming pictures in Mandarin (41a, left) and English (41b, right), and the mean of median reaction time when switching into either of these languages. Error rates (proportion of all responses) are shown below each graph.

The second question asked if unbalanced bilinguals would show different patterns of switch costs at a range of RCIs as earlier experiments had suggested. Having specified the short RCI range (150 to 800 ms) and long RCI range (1,200 to 2,000 ms), we analyzed unbalanced bilinguals' switch cost RTs over each RCI range. Switch cost data was first prepared. RTs were based on the median RTs of each participant. For each group of bilinguals and for each language, cue-switch-only RTs were subtracted from both-switch RTs. This formed four sets of switch cost data, each representing the time taken to switch into one particular language (Mandarin or English) for each bilingual type (balanced or unbalanced).

A within-subject two-way ANOVA on unbalanced bilinguals' switch cost RTs with the factors language task (English, Mandarin) and RCI (150, 300, 500, 800 ms) showed that switching into English was significantly slower than switching into Mandarin, (1, 11) = 27.88, *p* < .0001. For the long RCI range, another within-subject two-way ANOVA with the factors language task (English, Mandarin) and RCI (1,200, 2,000 ms) did not show significant differences between switching into English and Mandarin, *F* (1, 11) = .002, *p* = .96. There were no significant interactions. Thus, the analyses on unbalanced bilinguals' switch costs indicate a pattern of asymmetry at the short RCI, and a pattern of switch cost symmetry at the long RCI. Switch cost RTs of balanced bilinguals were next submitted to a within-subject two-way ANOVA with the factors language task (English, Mandarin) and RCI (150, 300, 500, 800, 1,200, 2,000 ms). This did not show any main effects (all *ps* > .05) or significant interactions (all *ps* > .05). The lack of interactions of RCI by language switch costs for both groups indicate that switch costs did not vary with the RCI. This answers the third question which was interested if task set inertia could account for language switch costs. Switch costs did not reduce as the RCI increased, indicating that the dissipation pattern encountered in the task domain was not replicated in this experiment.



Figures 42a and 42b: Graphs showing the mean of median reaction time of unbalanced bilinguals (42a, top) and balanced bilinguals (42b, bottom) when naming a picture correctly in Mandarin followed by naming another picture correctly in English (blue line) and naming a picture correctly in English followed by naming another picture correctly in Mandarin (red line).

Discussion

Experiment 4 was conducted on the basis of the findings of Experiments 3A and 3B. These findings were that unbalanced bilinguals did not, overall, show significant Mandarin switch costs when the RCI was 160 ms (Experiment 3A) but showed them when the RCI was 900 ms (Experiment 3B). Unbalanced bilinguals had also showed asymmetrical switch costs when the RCI was 160 ms and but showed symmetrical switch costs when the RCI was 900 ms. Therefore, in Experiment 4, we examined language switching behaviour at a range of

RCI, and were interested in unbalanced bilinguals' patterns of Mandarin switch costs, as well as overall switch costs.

In this experiment, unbalanced bilinguals showed the predicted behaviour – Mandarin switch costs were demonstrated only at a long RCI, and switch costs were asymmetrical at a short RCI but symmetrical at a long RCI. There was an unexpected main effect of RCI on the Mandarin task, indicating that Mandarin both-switch RT was significantly higher when the RCI was long. Balanced bilinguals demonstrated switch costs for switching into each language, and also showed their expected pattern of switch cost symmetry. Another aim of the experiment was to examine task set dissipation. Switch costs did not decrease as the RCI increased, indicating that the theory of task set inertia could not be wholly applied to language switching behaviour over the RCI. These results are discussed below.

The finding that unbalanced bilinguals showed Mandarin switch costs only at a long RCI lends some weight to our interpretation that in order to repeat a response in Mandarin, unbalanced bilinguals had to overcome interference from the Mandarin representation activated in the previous trial. However, this is speculative insofar as there was no significant RCI by Mandarin cue-switch-only trial interaction. A significant interaction would have indicated that as the RCI got longer, unbalanced bilinguals reduced the time taken to continue repeating in Mandarin. This would also have suggested then that a form of persisting activation from the previous trial interfered less in the present trial as the RCI got longer. One possibility why unbalanced bilinguals did not show a decreasing trend in cue-switch-only trials is that they may not have been passively waiting for the next cue after responding in Mandarin. Not waiting for the cue would have disrupted potential activation that was dissipating in the previous trial. By this, it is meant that unbalanced bilinguals could have been engaging other processes before the onset of the cue. This is supported by the finding of a main effect of RCI showing that unbalanced bilinguals were taking a significantly longer time to perform Mandarin both-switch trials at a longer RCI, specifically at the RCI range of 1,200 to 2,000 ms.

Our interpretation of this is that after waiting for approximately 1,000 ms from the last Mandarin response, unbalanced bilinguals would tend to configure towards English without the influence of a cue to do so. They do this presumably because it is the language they are more comfortable with; they also do this despite just having completed a Mandarin task. This interpretation is compatible with the notion that unbalanced bilinguals have to deal with carryover Mandarin activation, but this occurs within 1,000 ms, before they exercise the tendency to slip back into English. This also means that following a Mandarin response, the longer an English cue of the next trial is delayed, the easier it will be to respond. Figure 40b largely supports this, but future research is required to assess its significance. The possibility that unbalanced bilinguals may be in the process of engaging the settings of their preferred language also explains why we would not expect their switch costs to decrease over the RCI (although they would display overall Mandarin switch costs when the RCI is adequate, as suggested by our findings).

It is noted that even though no significant reduction of switch costs over the RCI (150 to 2,000 ms) was demonstrated, figures 42a and 42b reveal distinct patterns between the two groups of bilinguals. Compared with the switch costs of unbalanced bilinguals, balanced bilinguals showed less variability in their switch cost pattern. In another experiment similar to the present experiment, Meiran et al. (2000) had held the CSI constant and demonstrated a significant switch cost reduction over a RCI range of 132 to 3,032 ms. This suggests that the process of task set dissipation is a slow one, and given the perceptible overall decline of balanced bilinguals’ switch costs, there is a possibility that with a longer RCI range than what was set, balanced bilinguals may show a stronger pattern of decline. Balanced bilinguals also appeared to be less prone to showing unpredictable patterns for switching into Mandarin. Throughout this experiment, they demonstrated switch costs in each language, and showed symmetrical switch costs. This was also the case in Experiment 3B. Since their behaviour appears to be reliable, their unusual result of not showing significant Mandarin switch costs in Experiment 3A could have been an anomaly where perhaps balanced bilinguals responded carefully when naming in Mandarin such that there were no differences between repeating in or switching to Mandarin.

Unbalanced bilinguals showed asymmetrical switch costs at a short RCI (150 to 800 ms), and symmetrical switch costs at a long RCI (1,200 to 2,000 ms), giving support to the predictions we had set out to test. The finding of symmetrical costs is unusual with this group, however, the observation that unbalanced bilinguals took longer to go from naming in English to Mandarin at a long RCI may clarify why this happens. As suggested above, this finding may indicate that unbalanced bilinguals were configuring back to English when given sufficient time. This behaviour, at a long RCI, would have lowered the cost of switching into English, which would approximate the magnitude of Mandarin switch costs.

This idea is in agreement with a recent language switching study carried out by Christoffels et al. (2007). In the study, unbalanced bilinguals showed symmetrical switch costs. The RCI used was relatively longer (1,800 to 2,100 ms) compared with other studies that have reported only asymmetrical switch costs in unbalanced bilinguals (0 to 1,500 ms) (e.g., Costa & Santesteban, 2004; Finkbeiner et al., 2006; Jackson et al., 2001; Meuter & Allport, 1999). Christoffels et al. speculated that language factors, such as the bilinguals' speaking environment, mediated their switching ability such that subtle effects of proficiency were overrided. Our finding suggests a different explanation. We think that the bilinguals could have used the available time to reconfigure into L1 while waiting for the cue. This would have made it easier to switch into L1 by the time the stimulus appeared, and thus, L1 switch costs could have reduced to be symmetrical with L2 switch costs.

Overall, to return to task switching theory, an important finding across Experiments 3A and 3B was that switch costs did not decrease as the CSI increased, prompting us to question if switch costs would decrease as the RCI increased, indicating a pattern of dissipation rather than reconfiguration. This was not evident in the switch cost data for either group of bilinguals, for each of their languages. The null finding does not rule out the possibility that some form of carryover interference decayed over time, but it indicates that task set inertia cannot fully explain language switch costs, and that some other factor may be affecting switch costs. Since experiments 3A and 3B have also shown that task set reconfiguration is inadequate in predicting language switch costs over the CSI, the larger implication of this null effect is that the assumptions that task set inertia and task set reconfiguration hold – that participants wait passively for the next cue in the RCI and actively prepare for the next task in the CSI – are not readily applied to language switching; this is despite putting in place methods to encourage reconfiguration after the cue.

CHAPTER 9 – GENERAL DISCUSSION AND CONCLUSION

This thesis arose as a reaction to several problems identified in research on bilingual language control. Predictions of a bilingual advantage in non-language suppression tasks have not been consistent (see Hilchey and Klein, 2011) and whether or not the source of this advantage came from the experience of being bilingual had not yet been examined. In language switching, initial patterns of switch cost asymmetry and symmetry seen across language (Jackson et al., 2001; Meuter & Allport, 1999) and non-language domains (Allport et al., 1994) gave indications of a common suppression mechanism behind the control of both language and non-language task sets. The predictability of these switch cost patterns were directly related to the proficiency (Green, 1998), or the strength (Allport et al., 1994), of a task set. Reported switch cost patterns that did not follow the predicted pattern raised questions about this view (Costa & Santesteban, 2004; Costa et al., 2006). Examining a separate pattern of switch cost – one that reduced as the cue-stimulus interval (CSI) increased – promised some answers to this question (Monsell & Mizon, 2006). Related to this was examining whether a language task dissipated, and if it did, would it show the same response-cue interval (RCI) patterns as a dissipating non-language task (e.g., Meiran et al.). Prior to the experiments reported here, these switch cost patterns had not yet been studied in language switching. As a pre-requisite to looking into these patterns, we designed a novel language switching method that controlled for cue-effects to ensure that the data collected would reflect true language switching behaviour. This had the additional purpose of validating the picture-naming language switching method which most of the language switching community use in their own experiments; missing from these experiments however were steps taken to control for cue confounds. In short, the experiments reported in this thesis examined issues related to the bilingual advantage (Experiments 1 and 2) as well as language switching itself (Experiments 3A, 3B, and 4).

Synopsis of Results

First, we examined whether the bilingual advantage in interference suppression could be demonstrated in both language and non-language tasks. This would tell us if language experience in suppressing a language translated to gains in non-language suppression. In Experiment 1, young adult monolinguals and bilinguals were instructed to indicate the direction of a target arrow and ignore the distraction presented by irrelevant arrows that appeared on each side of the target. No significant differences were found between the groups. This led us to question Green's (1998) assumption that bilinguals transferred their language suppressing ability to the non-language domain. In Experiment 2, we tested a different group of monolinguals and bilinguals of the similar age range on a task that tapped into suppressing two aspects of language. They performed a novel picture-word interference task that required them to ignore semantically-related distractor words, or to avoid executing a wrong language task. The results again showed that bilinguals did not enjoy any advantage in suppressing these two forms of language interference.

Second, we examined bilingual language switching behaviour. We used a novel language switching paradigm that controlled for the effects of cue switches in language switches. With this paradigm, we looked at three kinds of task switching patterns in Experiments 3A, 3B, and 4, and determined if these patterns could be replicated in the language switching domain. In the order that these topics appear in the discussion, these were switch cost patterns associated with the reconfiguration of a task set, the dissipation of a task set, and the asymmetric or symmetric suppression of a task set. With regard to controlling for cue switch effects, the results showed that language switch data was not confounded with cue switching, on the condition that the RCI was sufficiently long for unbalanced bilinguals to demonstrate switch costs of their weaker language. On the switch cost patterns of interest, unbalanced and balanced bilinguals did not show patterns of reconfiguration and dissipation as seen in the task domain, suggesting that these processes were not analogous to those in the language switching. Switch cost symmetry was largely, and predictably, demonstrated by balanced bilinguals. However, unbalanced bilinguals showed switch cost asymmetry when the RCI was short, and switch cost symmetry when the RCI was long. We discuss these results below, beginning with our findings on the bilingual advantage.

The Bilingual Advantage

A natural interpretation of the null results of Experiments 1 and 2 is that because bilinguals did not show an advantage over monolinguals in tasks of non-language and language interference suppression, the assumption that (a) suppression is responsible for language selection (Green, 1998), and the hypothesis that (b) sufficient practice in suppressing competing language units enhances general interference suppression (Bialystok et al., 2004), must be re-examined. First, we consider (a). In rejecting (a), it is necessary to consider alternate accounts of language selection, bearing in mind that they must explain how bilinguals are able to accurately select from two equally activated lemmas. However, as it will be shown, there is no simple way to dismiss (a) and that (b) is the more likely scenario.

One of the alternate accounts of language selection is Costa et al's (1999) language-specific model. Costa et al. (1999) propose that lemmas from the non-target language, though activated, do not enter competition for selection. They provide as evidence from their picture-word interference study, that despite findings of semantically-related second language (L2) distractors interfering with first language (L1) picture-naming (Hermans et al., 1998; van Heuven et al., 2008), there is a situation where L2 distractors actually facilitate picture-naming. This is when L2 distractors are the translations of the names of the pictures. Costa et al. explain that the distractor translation lemma activates a link to its counterpart target lemma in the target language, and then transmits information to that lemma. This raises the activation level of the target lemma and results in its quicker selection. Since selection occurs through activation levels, suppression is unnecessary. Costa et al. argue that if the non-target language competed in the selection, the translation lemma would have interfered with the selection of the target lemma.

However, although Costa et al. (1999) provide a plausible account for their model, their result can also be explained by the language-nonspecific model. Relevant to this alternative explanation is the Stroop effect. Research in this area has established that words present to participants a compulsion to decode them even though the act is not required for the task at hand (see Macleod, 1991). This explains why a colour word that is in conflict with its colour ink interferes more with colour-naming than word-naming. Similarly, in the picture-word interference task, a semantically-related word to the picture interferes more with picture-naming than an unrelated word (Starreveld & La Heij, 1995). The consensus is that word-reading occurs through highly practiced pathways which result in rapid word retrieval, with some even arguing this process to be automatic (Brown, Gore, & Carr, 2002; LaBerge & Samuels, 1974). In contrast, naming a colour or picture requires relatively more effort (Macleod, 1991). This suggests that when participants are faced with a picture stimulus and a distractor word, they will likely decode the word before the picture. If the distractor is the translation of the picture, it directly activates the conceptual representation of the picture. This early activation of the concept primes a response in the corresponding lemma in the target language, and ultimately lowers picture-naming reaction time (RT) in the target language. Thus, although the translation lemma is rejected based on its language membership, other properties present in its language “tag” (Green, 1998, p. 71) are relevant to the picture concept; this increases the activation level of the concept to be named and results in decreased naming RT.

Yet another account conceives of selection through a speaker’s intention (Finkbeiner et al., 2006; La Heij, 2005). These models are heavily reliant on the target word possessing sufficient cues to facilitate accurate selection. For example, La Heij’s solution to bilingual lexical selection is that each lexical representation contains sufficient language cues that communicate information on the affective, pragmatic, and linguistic features of the target word. With cues guiding the selection effort, inhibition need not be unnecessarily invoked since the target word will be the most highly activated candidate. The word *dog*, for instance, would have cues in its preverbal profile that make it distinct from the word *cat* (e.g., a cue that means “an animal that barks”) and perhaps, another cue distinguishing it from membership of the L2 system. The word that comprises the sum of cues that most closely matches the target concept raises its activation level and guides the selection mechanism to attend to it. Since the most relevant word naturally gains the highest activation, no inhibition is needed.

This is a plausible model. However, a basic weakness this model shares with the language specific model is that they are unable to account for language switching phenomena. The language specific model does not mention how it applies to language switching. If the selection mechanism does not consider L2 in selecting L1, why should L1/L2 and L2/L1 switches result in differential patterns? With respect to cue-guided selection, if indeed the availability of a lemma is identified by the number of cues, then bilinguals should always find it easier to select lemmas from their stronger language than their weaker one. This description is intuitive, but not consistent with language switch literature. As was reviewed in Chapter 4, there is substantial evidence showing that bilinguals take longer to select their stronger language if they had just responded in the weaker language than vice versa. This pattern of asymmetrical switch costs is not easily explained by non-suppression accounts; the weaknesses of these models make the IC model the favoured view (e.g., Bialystok et al., 2012)

In addition to this, Bialystok, Craik, and Luk (2012) take as indirect evidence of the involvement of suppression processes in bilingual language control, the joint activation of bilinguals' two languages. For example, there is the influence of the unused language on the target language in picture-word interference tasks that has been mentioned above (Hermans et al., 1998; van Heuven et al., 2008). Also, research on language disorders document case studies of patients who are unable to speak in the language of their choice (Aglioti & Fabbro, 1993; Fabbro, Skrap, & Aglioti, 2000) despite it being their dominant language (Aglioti & Fabbro, 1993). Using eye-tracking technology, a study that required bilinguals to select a target picture from four choices found that they were distracted by an irrelevant picture whose name shared phonological properties with the target picture name, even though the pictures were semantically unrelated (Marian, Spivey, & Hirsch, 2003). Finally, on the basis that brain activation levels reveal the extent of involvement of language processing, neuroimaging research shows that the unused language is active despite instruction to use only the other language (Martin, Dering, Thomas, & Thierry, 2009; Rodriguez-Fornells et al., 2005). The connection between this body of research and that of suppression is that bilinguals must have a suppression mechanism that allows them to cope with constant interference of the irrelevant language. If it is premature to rule out the role of suppression processes in language control, then the remaining question is whether or not the bilingual experience of suppressing the irrelevant language boosts the ability to ignore interference. In the next proceeding paragraphs, we consider (b), the claim that constantly suppressing competing language units hones skills of interference suppression.

This claim was derived from studies on children tasked with making a response while having to ignore information that interfered with the selection of that response. Bilingual children have been reported to outperform monolingual children in being able to focus on a word's meaning and ignore its form (Ben-Zeev, 1977; Ianco-Worall, 1972), correct a sentence's grammatical error and resist correcting its semantic anomaly (Bialystok, 1986), and work out a visual, or numerical, problem in the presence of perceptual distractors (Bialystok & Codd, 1997; Bialystok & Majumder, 1998). The research in this area strongly suggests that bilinguals hold a cognitive advantage over monolinguals in suppressing interfering information. A problem with these studies is that they have only been used on children, and for practical reasons, are not suitable for adults whose language and cognitive skills have matured. Therefore, the motivation for using the Simon task and the flanker task was so that the bilingual advantage could be compared across age groups. Within the number of studies that has employed this method, however, only older adults have been reported to show the advantage (Bialystok et al., 2008). In support of this are the results of Experiments 1 and 2 which did not show any evidence of a bilingual advantage in interference suppression in younger adults.

All of this data suggest that (b) should be interpreted with caution. Since the literature is in favour of the involvement of suppression processes in bilingual discourse, and since there is strong evidence of a bilingual advantage in research on children, then perhaps the consequence of managing an extra language leads to the advantage of another cognitive ability that is *not* interference suppression. Specifically, the advantage may have more to do with influencing bilinguals' skills of monitoring a situation, rather than suppressing interference in that same situation. Newer studies probing the bilingual ability to monitor non-language information so far lend support to this view (Abutalebi et al., 2011; Costa, Hernanez, Costa-Faidella, & Sebastian-Galles, 2009; Singh & Mishra, 2013).

Costa et al. (2009) first arrived at this conjecture based on the unexplained observations of a bilingual advantage in situations *without* conflict, that is, congruent trials in the Simon task (Bialystok et al., 2004; Martin-Rhee & Bialystok, 2008) and the flanker task (Emmorey et al., 2008). This revealed to Costa et al. that the source of any bilingual advantage seen in tasks of conflict originated from a separate cognitive process, possibly the monitoring process. To test this hypothesis, Costa et al. (2009) manipulated the degree of monitoring required in four versions of a type of flanker task. This was done by setting the percentage of congruent trials at 8% in the first version, 50% in the second, 75% in the third, and 92% in the fourth. The rest of the trials were incongruent. Presumably, if participants were not required to adjust frequently to a different trial type, their monitoring system would be less involved. Therefore, it was predicted that when congruent trials made up 8% or 92% of all trials, the young adult bilinguals would not show an advantage against monolinguals. The bilinguals would, however, show an advantage for tasks that contained 50% or 75% congruent trials. The results supported these predictions, except that the effect was not as strong in the 75% condition.

Our bilinguals in Experiment 1 did not show any advantage on congruent trials. To recap, Experiment 1 ran a flanker task with six conditions. Out of these six conditions, only two conditions (Control and Same Congruent) did not require suppression (interference suppression or response inhibition). If an incongruent trial requires one to exercise suppression, this would describe approximately 75% of all trials in Experiment 1. In previous studies where the advantage in congruent trials has been reported (Bialystok et al., 2004; Martin-Rhee & Bialystok, 2008), the percentage of congruent trials versus incongruent trials was 50%. In Costa et al's (2009) experiment, the bilingual advantage in congruent trials was shown in the 50% condition. The results were not as straightforward in the 75% condition of their experiment as an advantage was only seen in the first out of three blocks. Taken together, these suggest that Experiment 1 in our study may constitute a somewhat low-monitoring task and therefore not did not provide a strong context for bilinguals to perform as quickly as they could have had, had the 1:3 nonsuppression-to-suppression mapping been altered to 1:1. This would explain why there was no advantage on congruent trials in Experiment 1.

There is still the question of why a bilingual advantage in interference suppression has been seen in other samples (Bialystok et al., 2004; Bialystok et al., 2008). Our null results in interference suppression in young adults, plus the observation that a bilingual advantage in interference suppression has been confined to older adults, suggest that RT-based tests may not be sufficient in detecting group differences in interference suppression until adults approach their older years. According to Bialystok et al. (2005) who rely on models of aging (e.g., Hasher & Zacks, 1988) for their view, older adults are less able to control the contents of their working memory and therefore have lower executive control than young adults. This implies that young adults across language groups have strong executive control. If there are inherent language processing differences between monolinguals and bilinguals as the literature suggests, then potentially, young adult bilinguals may approach interference suppression tasks differently from young adult monolinguals, but this may be evident only through more advanced techniques that probe how the brain processes interfering stimuli.

Recently, Luk, Anderson, Craik, Grady, and Bialystok (2010) used both behavioural and neuroimaging techniques to examine flanker task performance in young adult monolinguals and bilinguals. The version of the flanker task administered consisted of five conditions, go, no-go, congruent, incongruent, and a baseline. In line with our results, the behavioural data of this experiment did not show any significant between-group differences for each of these trials, indicating that RT analyses of interference suppression and response inhibition did not support the bilingual advantage hypothesis, or that monolinguals and bilinguals responded differently to handling interference. However, neuroimaging data showed different brain activation patterns in the two groups. Monolinguals, relative to bilinguals, activated a different set of brain areas during interference suppression, but they engaged the same brain areas as bilinguals during response inhibition. Bilinguals on the other hand activated the same brain areas for interference suppression and response inhibition trials. This suggested to the authors that the experience of being bilingual influenced the brain areas responsible for the control of interference, which in bilinguals was reflected in the recruitment of an extensive, general network of attention to address conflicting information.

The lack of any imaging data in our examination of the bilingual advantage prevents us from making any strong claims. However, based on particular similarities in the design of Luk et al's (2010) experiment and ours (mean age of English monolinguals = 22 years; mean age of bilinguals with English as one of their languages = 20 years; experimental stimuli = flanker task) we anticipate that the behaviour of our sample of bilinguals might approximate that of this study. If we were to speculate further in this vein, the larger implication of our results is that Bialystok's (1986) assumption that "[executive] tasks that are high in their demands for control of attention are solved better by bilinguals than monolinguals … [because of their] ability to control attention when there is misleading information" (p. 179) has to be revised. Specifically, executive control tasks that are better solved by bilinguals are those embedded in a high-monitoring context, which may not necessarily contain misleading information. To put it another way, the executive function of suppressing interference may have less to do with language than the executive function of directing attention to relevant task features. Therefore, language control at the level of lemma selection could plausibly be a purely linguistic process whereas this mechanism may be executive in nature at the level of lemma-monitoring.

Language switching

If we consider the possibility that linguistic and nonlinguistic processes overlap, then this directly implies that linguistic and nonlinguistic functioning at some point converge on a common mechanism. The IC model achieves this by incorporating executive function into language processing and is therefore necessarily in some way limited by the workings of executive control and the processes associated with it; specific to this thesis are task set dissipation, task set reconfiguration, and executive inhibition.

Although the results of Experiments 1 and 2 show that bilinguals do not have an advantage in executive control, they do not reveal whether or not executive control is involved in bilingual language processing. Experiments 3 and 4 make use of the understanding of how executive control works in the ask domain, and examine if this behaviour is similarly expressed in the language domain. However, the popular paradigm used for generating these patterns is confounded by a cue-switching effect. Before applying the paradigm to investigate switch costs, we modified it to control for cue effects. In addition to controlling for cue effects, we used a cued language switching procedure so that the time between the last response and the next stimulus would be divided into the RCI and the CSI. This allowed us to examine the contributions of each interval independently. A longer RCI allows a task set carried over from the previous trial to dissipate; a longer CSI allows an existing task set to reconfigure. Both of these manipulations are expected to cause switch costs to reduce (Meiran et al. 2000; Monsell & Mizon, 2006).

Importantly, these hypotheses of dissipation and reconfiguration are steeped in the assumption that a participant begins to prepare towards a new task once the cue appears. The logical extension of our failure to find the signatures associated with task set dissipation and reconfiguration – a reduction of switch costs over the RCI (dissipation) or CSI (reconfiguration) – is that this assumption was not met.

With respect to the CSI, it may be that in the context of naming pictures in language switching, one may be unable to prepare the control system towards a new goal, without knowing at least in part, features of the upcoming stimulus. In studies where the reduction in switch cost has been replicated, instructional tasks were highly specific and arguably entailed a shallower kind of processing compared with lexical access. Some examples of these tasks are switching between identifying a shape or colour (Monsell & Mizon, 2006, Experiment 4), making a judgment on an object’s big or small size (Monsell & Mizon, 2006, Experiment 2), and judging a number’s parity or magnitude (Logan & Bundesen, 2003). In these tasks, the ability to anticipate a stimulus is much higher given the relatively limited array of stimuli in each case, as well as the execution of only one of two responses (although Monsell and

Mizon have four options in their shape or colour exercise). For example, in a numerical task, participants can anticipate the numbers “1” to “9”, utilize a strategy of visually imagining which of these numbers may appear on the monitor and thus bias particular responses relevant to what is expected. This sort of strategic approach can reasonably improve over time since an increasing number of responses from a small finite stimuli set, all of which can be held in the working memory, can be considered.

In the present picture-naming experiments, even with knowledge of which language they are expected to respond in, it is impossible to predict which picture will appear, given the large number of picture stimuli (260) used. Therefore, it might be that after processing the language cue, bilinguals adopted a “wait for the picture to appear then respond” approach. If this is true, then lexical access begins only after the onset of the stimulus. The pattern that results is a reflection of how closely linked a picture name is to the bilingual lexicon in that particular language. For example, upon receipt of a Mandarin cue, the participant prepares to respond in Mandarin and waits for the picture to appear. If a familiar picture appears, it will be named more quickly than if an unfamiliar picture had appeared. Since each picture is linked to its response to different degrees of familiarity, they would arguably involve different rates of reconfiguration. In preparing the picture stimuli for all experiments, care had been taken to control for picture familiarity, amongst other factors. However, due to sample variance, it is unlikely that each participant would have found each stimulus equally familiar. Therefore, the irregular switch cost patterns across an increasing CSI may actually more closely depict language switching processes.

A few studies provide some support for our interpretation. Costa and Santesteban (2004) showed that even with 10 picture-naming stimuli, bilinguals failed to reduce their switch costs at an increased CSI. Philipp et al. (2007) also showed that with digit-naming (“1” to “9”) stimuli, unbalanced bilinguals’ switch costs increased at a long CSI. Using a switching design that required participants to remember switching sequences, Declerck et al. (2013) showed that predictability did not result in an improvement at a long CSI. Although it is noted that the number of trials, nature of stimuli, procedure of stimuli presentation were different in each of these studies, and were also different from the present set of experiments, the evidence largely indicate that the CSI is not used for the systematic preparation of verbal responses.

This account of CSI processes is not problematic with our findings on the RCI. Although we had not observed a significant interaction between the RCI and switch costs in both groups of bilinguals, the influence of the RCI was expressed in other switch cost patterns exhibited by unbalanced bilinguals. This was the pattern we had observed:

- When the RCI was 160 ms, unbalanced bilinguals did not show significant Mandarin switch costs. Their pattern of switching between English and Mandarin was asymmetrical.
- When the RCI was increased to 900 ms, significant Mandarin switch costs emerged. Unbalanced bilinguals showed symmetrical switch costs.
- When the RCI varied between 160 to 2,000 ms, unbalanced bilinguals' Mandarin switch costs were not significant from the RCI range of 160 to 800 ms, but significant from 1,200 to 2,000 ms. Concordant with the points before, asymmetrical switch costs were observed in the short RCI range and symmetrical switch costs in the long RCI range.
- Balanced bilinguals showed symmetrical switch costs throughout our testing.

The interpretation we arrive at is that, at a short RCI, unbalanced bilinguals experience *within-language* interference of the weaker of their two languages. This behaviour contributes to asymmetrical switching and also explains non-significant Mandarin switch costs only at a short RCI. At a long RCI, they begin to reconfigure to their dominant language if the RCI runs long enough; this behaviour contributes to symmetrical switching.

First, we consider the notion of within-language interference. In theories of task- and language switching, interference is experienced only when the information retrieved in a present trial is incongruent with that in the previous trial. This is the basis for why a switch cost (in information) occurs (Allport & Wylie, 2000). This information might comprise the task goal, the language, the representations of stimuli meaning, and response set. Along the same line of reasoning, if no costs are seen, it is implied that the information carried over from the previous task set was adequately similar that any interference experienced was non-significant (Allport et al., 1994) or that little reconfiguration needed to be carried out to suit a new response (Rogers & Monsell, 1995). These instances are characteristic of repeat trials, where the same response set can be maintained with minimal incongruence presented by a previous task set. In our experiments, our problem stems from unbalanced bilinguals *not* experiencing a significant cost when they switched from English to Mandarin, compared with repeating a response in Mandarin. Clearly, such a switch requires a dramatic revision of information, and so the question is how repeating a response in Mandarin could attain RTs high enough to render these changes non-significant. The possibility we entertain is that "language schemas" (Green, 1998, p. 69) of a weak language are largely represented differently within the language so that continually repeating a response requires engaging new settings to suit each response. This change in within-language settings takes as much time as a between-language change and speaks directly to the structure of the bilingual lexicon.

Lemmas of a weak language are less stable forms in the bilingual lexicon (Kroll & Stewart, 1994) and are differently retrieved from more stable word forms (Ecke & Garrett, 1998). Dominant language lemmas have the advantage of being strongly mapped to their conceptual representations where speakers can access them via a meaning-oriented route, exploit existing "linguistic categories" (Pavlenko, 2009, p. 125), and swiftly select words. These mental categories offer speakers a way to organise meanings around the common properties of lemmas. In line with spreading activation models of lexical access (Bock & Levelt, 1994; Collins & Loftus, 1975), calling up a single concept triggers the activation of several related concepts that in turn activate a cluster of related lexical representations, a process likely facilitated by categorical organisation. Studies demonstrating the influence of word frequency (Barry, Morrison, & Ellis, 1997; Jescheniak & Levelt, 1994) and phonological similarity (Knupsky & Amrhein, 2007; Peterson & Savoy, 1998) on lexical access are evidence of the complex inter-connectedness of a well-developed semantic network. From this, it is easy to see how the habitual activation level of a dominant language is high, and retrieving words from this language is rapid and efficient. This is possible only if speakers have in-depth word knowledge of the concepts in a lexicon, an unlikely scenario with respect to unbalanced bilinguals and their second language. In the latter case, lemmas in the weak language may be characterized by individuated links and therefore lack unifying traits which would have assisted in efficient retrieval. This leads to a reliance on dominant language to mediate the retrieval process (Kroll & Stewart, 1994; Malt & Sloman, 2003). If the reliance on dominant language links is extensive, then translating this information into a response for the weaker language will require considerable switching between lexicons. Therefore, for unbalanced bilinguals, the task of responding in a weak language could plausibly approach that of switching between languages.

There is the issue of why non-significant switch costs in the weak language has not been reported in language switching. There are two possible reasons. Firstly, ours is the only study that has used a broad range of picture stimuli which raised the difficulty level of picture-naming. This is reflected in the high error rate, especially that of unbalanced bilinguals. Unbalanced bilinguals would have had to resort to tapping into their dominant language to bolster retrieval efforts in their weaker language, while balanced bilinguals may have done the same but to a much lesser extent. As argued above, the mediation of the dominant language on the weaker language would raise baseline naming RT of the weak language. The next reason is that the small value of RCI (160 ms), the RCI within which significant Mandarin switch costs could not be demonstrated, is seldom employed in language switching. Therefore, in one sense, the bilingual participants in these studies have always had enough time to resolve irrelevant settings of an abandoned representation in the weak language and engage the relevant ones for a new response in the same language.

The idea that carryover activation of a weakly-supported language task set may have an adverse, rather than facilitative, effect on an existing task set in the same language questions the limits of the benefits of task repetition. In non-language task switch theory, this view espouses that in a repeat trial, relevant carryover task settings eliminate the need to revise present settings so that response selection is expedited (Horoufchin et al., 2011). Our data show that for both groups of bilinguals, and for both languages, task repetition benefit was not applicable. As the RCI increased, for both groups, there was no increase in the repeat trial RT for each language (since the beneficial activation would dissipate as the RCI wore on), nor was there a decrease in switch trial RT for each language (since there would be the greatest conflict at the point of switching into a new language when the RCI is short). This suggests that the influence of a previous language trial on the subsequent one is different from that of a non-language trial acting on a subsequent non-language trial.

Instead, at a longer RCI, unbalanced bilinguals took longer to name in Mandarin after responding in English. This brings us to our next point: bilinguals may maintain a habitual activation level of each language so that if one language is suppressed below its habituated level, over time, the activation may be restored if left undisturbed.

The set of findings that has led us to this hypothesis is unbalanced bilinguals' display of switch cost symmetry at a long RCI. It will be recalled that the IC model predicts larger switch costs for the dominant language than the weaker language. Symmetrical switch costs may then arise from either a decrease in switch costs of the dominant language or an increase of that in the weaker language. The finding that unbalanced bilinguals took longer to name in Mandarin following an English response under a long RCI suggests that they tend to restore the mental settings for the English system when given the opportunity. This leads to lower English switch costs which then contributes to an outcome of symmetrical switch costs.

To our knowledge, except for two studies, language switching experiments have typically used an RCI in the range of 0 to 1,500 ms (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999). An exception is the study by Christoffels et al. (2007). The researchers conducted a language switching study examining unbalanced bilinguals' brain activations when naming pictures with phonologically similar names. The authors set the RCI at a range of 1,800 to 2,000 ms, presumably to allow a greater rest period between brain activation readings. They found, unexpectedly, that unbalanced bilinguals incurred symmetrical costs for switching between L1 and L2. The authors reasoned that switching between two languages for which they had obtained robust switch costs may have overridden the subtle effects of proficiency. However, given the numerous studies which have consistently shown equally strong effects of switch costs without obtaining switch cost symmetry (e.g., Meuter & Allport, 1999), it seems more plausible that the long RCI had effected a configuration into L1, and lowered the cost of switching into L1, thus reducing the gap between L1 and L2 switch costs, thus resulting in a pattern of switch cost symmetry.

Is Language Control the same as Executive Control?

An overarching question we had sought to address was whether language control was subsidiary to executive control. The argument advanced in the beginning of the thesis was if bilinguals controlled their languages with executive processes, then bilinguals would show an advantage over monolinguals in tasks of executive control, and, balanced and unbalanced bilinguals would show language switching patterns that could be explained through task switching theories. In general, the results do not provide compelling evidence that this is the case. One exception is that patterns of switch cost symmetry and asymmetry of balanced and unbalanced bilinguals largely held throughout the experiments. This gives support to the idea that the amount of suppression applied to each language is inversely proportional to their proficiency, a notion that parallels observations of the greater difficulty in suppressing a stronger task set relative to a weaker task set in non-language research (Allport et al., 1994). Although, based on our findings of unbalanced bilinguals showing symmetrical switch costs at an extended RCI, and including studies that have begun to find the same result in unbalanced bilinguals under a longer-than-average trial duration (Christoffels et al., 2007; Verhoef et al., 2009), theories of what language switch costs reflect may need to be revisited.

Costa et al. (2009) provide a new perspective on approaching this question. Potentially, the monitoring aspect of language control may hold some answers to the question. In this sense, the “supervisory” aspect of the Supervisory Attentional System (SAS), rather than its suppressing properties, is key to understanding the involvement of executive control in language control.

Calabria et al. (2012) provide yet another direction to gain insight into the language/executive control debate. The researchers believe that the practice bilinguals get in negotiating an extra language enhances the ability to *switch* between task sets, rather than one that allows them to cope with interference. Based on the robust findings of language switch cost asymmetry shown by unbalanced bilinguals (Jackson et al., 2001; Meuter & Allport, 1999; Philipp et al., 2007), and non-language switch cost asymmetry shown by participants switching between two non-language tasks of unequal strengths (Allport et al., 1994), Calabria et al. conceded that bilingual language processing entailed tapping into executive control. However, research has also shown the odd finding of balanced bilinguals showing symmetrical switch costs for switching between two languages of unequal proficiencies (Costa et al., 2004; Costa et al., 2006). From this, the researchers hypothesized that unless balanced bilinguals replicated the symmetrical pattern of switching between two non-language tasks of unequal strengths, language control processes overlapped with, but was not completely subordinate to, executive control. This was confirmed in their study that showed symmetrical costs incurred by balanced bilinguals when they switched between L1 and L3, or L1 and L2, but asymmetrical costs when they switched between two non-language tasks of unequal strengths. If Costa et al. (2006) is correct about balanced bilinguals employing an efficient control mechanism that allows them to carry out L1/L3 switches just as they do L1/L2 switches, then it appears that this efficiency is not carried over to the non-language switching domain where an asymmetry is still demonstrated if one of the non-language tasks is weaker than the other.

Limitations

Having discussed our results, it is important to note potential caveats to our study. The first is that the error rates in our language switching experiments were relatively high. This was likely due to two reasons. First, despite our efforts to norm stimuli, there appeared to be a naming difficulty in Mandarin for the Snodgrass and Vanderwart (1980) set which was developed for use with native English speakers. For example, Singaporean bilinguals reported difficulty in naming items such as *screwdriver, kettle,* or *hanger* in Mandarin as they would generally code-switch into English for these items. Next, we used a large number of stimuli compared with other language switching studies to obtain a more accurate depiction of the bilingual lexicon but this likely increased the difficulty of Mandarin-naming. The next caveat has to do with participant characteristics. Most of the participants were Singaporean. Having grown up in a multiracial nation-state, it was unavoidable that the “monolinguals” were exposed to other languages. The emphasis on English as the working language also meant that balanced bilinguals were dominant in English. Therefore, our monolinguals could plausibly be extremely unbalanced bilinguals, and our balanced bilinguals, more unbalanced than they reported themselves to be. These could have contributed to the non-significant results obtained in Experiments 1 and 2. At least two more reasons could also have contributed to non-significant results. The first of these is that the relatively small sample size of experimental groups could have lead to a cost in power, that would in turn have led to a difficulty in detecting interaction effects. The second is that certain variables known to affect bilingual ability were not controlled. These variables – socioeconomic status, working memory, vocabulary size etc. – were assumed to be constant but could have had a profound influence on performance. Therefore, aside from using larger sample sizes of bilinguals, future studies can look to profiling participants on more non-verbal variables.

Conclusion

With these caveats in mind, we conclude that the premise of the IC model – that language control is cognitive control – is undermined by our findings. We did not find evidence of a bilingual advantage in language or non-language interference suppression, nor were we able to reproduce the systematic switch cost reductions associated with task set reconfiguration or task set dissipation. We consider our findings on the bilingual advantage in young adults to be important because they are a first attempt to trace the phenomena, if it exists, to a language source. With newer research yielding similar null results in young adults (Paap & Greenberg, 2013), we suggest that the bilingual advantage as originally conceived (Bialystok et al., 2004) should be reconsidered. Our experiments on language switching represent novel explorations into pre-cue and post-cue processes of controlling language task sets. Despite the lack of RCI × switching and CSI × switching interactions, a crucial aspect of our work is that it is free of cue artefacts. In collecting such data, we showed that the picture-naming language switching paradigm is a viable method to studying language control. Future research is required to validate the effect of the RCI on demonstrating switch costs of unbalanced bilinguals' weaker language.

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Appendix A

Northwestern Bilingualism & Psycholinguistics Research Laboratory
Please cite Marian, Blumenfield, & Kaushanskaya (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech Language and Hearing Research, 50* (4), 940-967.

LANGUAGE EXPERIENCE and PROFICIENCY QUESTIONNAIRE (LEAP-Q)

Last Name		First Name		Today's Date	
Age		Date of Birth		Male ☐	Female ☐

(1) Please list all the languages you know **in order of dominance**.

1	**2**	**3**	**4**	**5**

(2) Please list all the languages you know **in order of acquisition** (your native language first).

1	**2**	**3**	**4**	**5**

(3) Please list what percentage of the time you are *currently* and *on average* exposed to each language.
(*Your percentages should add up to 100%*):

List language here:						Sum % 0
List percentage here:						

(4) When choosing to read a text available in all your languages, in what percentage of cases would you choose to read it in each of your languages? Assume that the original was in another language, which is unknown to you.
(*Your percentages should add up to 100%*):

List language here:						Sum % 0
List percentage here:						

(5) When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? Please report percent of total time.
(*Your percentages should add up to 100%*):

List language here:						Sum % 0
List percentage here:						

(6) Please name the cultures with which you identify. On a scale from zero to ten, please rate the extent to which you identify with each culture. (Examples of possible cultures include US-American, Chinese, Jewish-Orthodox, etc.):

List cultures here					
	(click here for scale)	(click here for scale)	(click here for scale)	(click here for scale)	(click here for scale)

(7) How many years of formal education do you have?
Choose either **(A) or (B)** to indicate your educational level.

(A)
Please check the education level(s) attained (or the approximate US equivalent to a degree obtained in another country):

☐ Less than High School
☐ High School
☐ Professional Training
☐ Some College
☐ College
☐ Some Graduate School
☐ Masters
☐ Ph.D./M.D./J.D.
☐ Others:

(B)
Please check all education level(s) attained

☐ Secondary School and before
☐ Secondary School
☐ Professional Training/Certification
☐ Institute of Tech. Education (ITE)
☐ Private School -
-please select highest level-
☐ International School -
-please select highest level-
☐ International Baccalaureate (IB)
☐ Integrated Programme
☐ Junior College
☐ Polytechnic
☐ Degree
☐ Masters
☐ Ph.D./M.D./J.D
☐ Others:

(8) Date of immigration to the USA, if applicable:
If you have ever immigrated to another country, please provide name of country and date of immigration here:
☐ This question does not apply to me.

(9) Have you ever had a vision problem ☐, hearing impairment ☐, language disability ☐, or learning disability ☐? (Check all applicable).
☐ I have no experience of the above problems.
If yes, please explain (including any corrections):

Write/type explanation here:	

Appendix A

LANGUAGE:

This is my -please select from pull-down menu- language.
All questions below refer to your knowledge of .

(1) Age when you … :

began acquiring :	became fluent in :	began reading in :	became fluent reading in :

(2) Please list the number of years and months you spent in each language environment:

	Years	Months
A country where is spoken.		
A family where is spoken.		
A school and/or working environment where is spoken.		

(3) On a scale from zero to ten, please select your *level of* ***proficiency*** in speaking, understanding, and reading from the scroll-down menus:

Speaking	(click here for scale)	Understanding spoken language	(click here for scale)	Reading	(click here for scale)

(4) On a scale from zero to ten, please select how much the following factors contributed to you learning :

Interacting with friends	(click here for pull-down scale)	Language tapes/self instruction	(click here for pull-down scale)
Interacting with family	(click here for pull-down scale)	Watching TV	(click here for pull-down scale)
Reading	(click here for pull-down scale)	Listening to the radio	(click here for pull-down scale)

(5) Please rate to what extent you are currently exposed to in the following contexts:

Interacting with friends	(click here for pull-down scale)	Language-lab/self instruction	(click here for pull-down scale)
Interacting with family	(click here for pull-down scale)	Watching TV	(click here for pull-down scale)
Reading	(click here for pull-down scale)	Listening to the radio/music	(click here for pull-down scale)

(6) In your perception, how much of a foreign accent do you have in ? (click here for pull-down scale)
(7) Please rate how frequently others identify you as a non-native speaker based on your accent in . (click here for pull-down scale)

LANGUAGE:

This is my -please select from pull-down menu- language.
All questions below refer to your knowledge of .

(1) Age when you … :

began acquiring :	became fluent in :	began reading in :	Became fluent reading in :

(2) Please list the number of years and months you spent in each language environment:

	Years	Months
A country where is spoken.		
A family where is spoken.		
A school and/or working environment where is spoken.		

(3) On a scale from zero to ten, please select your *level of* ***proficiency*** in speaking, understanding, and reading from the scroll-down menus:

Speaking	(click here for scale)	Understanding spoken language	(click here for scale)	Reading	(click here for scale)

(4) On a scale from zero to ten, please select how much the following factors contributed to you learning :

Interacting with friends	(click here for pull-down scale)	Language tapes/self instruction	(click here for pull-down scale)
Interacting with family	(click here for pull-down scale)	Watching TV	(click here for pull-down scale)
Reading	(click here for pull-down scale)	Listening to the radio	(click here for pull-down scale)

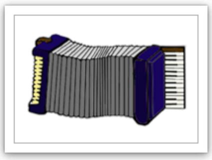
(5) Please rate to what extent you are currently exposed to in the following contexts:

Interacting with friends	(click here for pull-down scale)	Language-lab/self instruction	(click here for pull-down scale)
Interacting with family	(click here for pull-down scale)	Watching TV	(click here for pull-down scale)
Reading	(click here for pull-down scale)	Listening to the radio/music	(click here for pull-down scale)

(6) In your perception, how much of a foreign accent do you have in ? (click here for pull-down scale)
(7) Please rate how frequently others identify you as a non-native speaker based on your accent in . (click here for pull-down scale)

Appendix B

260 picture stimuli for Experiments 2, 3A, 3B, and 4 (the number labels that enumerate the pictures are their stored computer file names).



1.bmp

2.bmp

3.bmp

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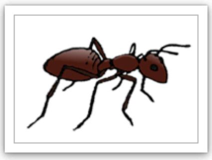
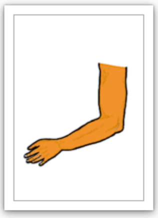
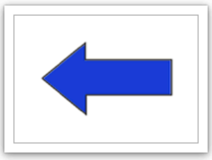


5.bmp

6.bmp



7.bmp



8.bmp

9.bmp

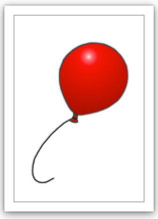
10.bmp

11.bmp

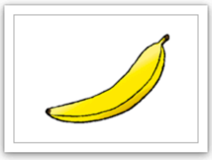
12.bmp

13.bmp

14.bmp



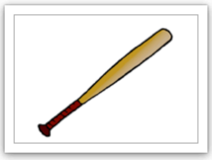
15.bmp



16.bmp

17.bmp

18.bmp



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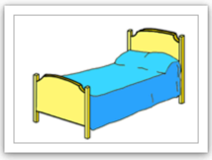
21.bmp



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24.bmp


25.bmp


26.bmp


27.bmp


28.bmp

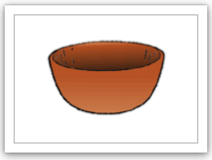

29.bmp


30.bmp


31.bmp


32.bmp


33.bmp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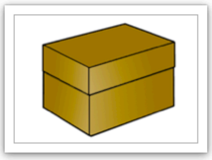
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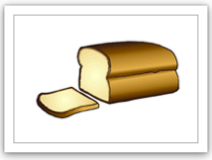
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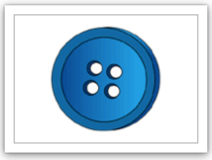
37.bmp


38.bmp


39.bmp


40.bmp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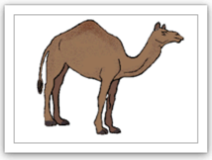
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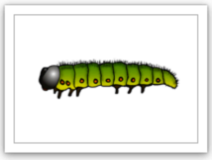
45.bmp


46.bmp


47.bmp


48.bmp


49.bmp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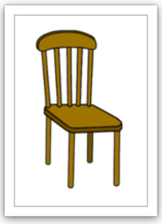
51.bmp


52.bmp

Appendix B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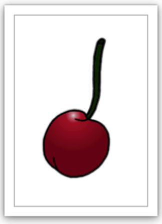
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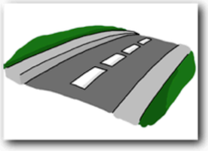
55.bmp


56.bmp


57.bmp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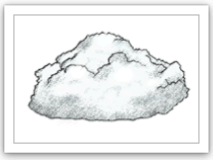
59.bmp

60.bmp


61.bmp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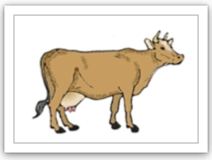
65.bmp


66.bmp


67.bmp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69.bmp


70.bmp


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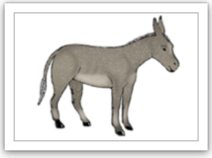
72.bmp


73.bmp


74.bmp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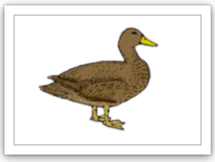
76.bmp


77.bmp


78.bmp


79.bmp


80.bmp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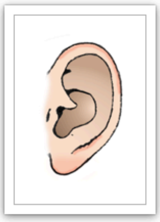
82.bmp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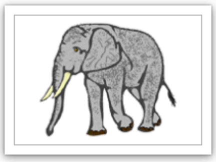
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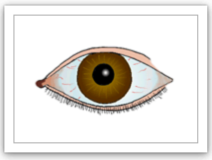
85.bmp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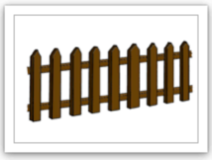
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88.bmp


89.bmp


90.bmp


91.bmp


92.bmp


93.bmp

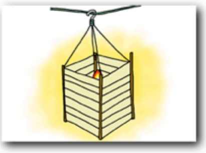

94.bmp


95.bmp


96.bmp


97.bmp


98.bmp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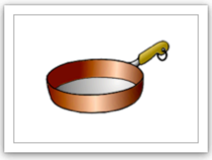
100.bmp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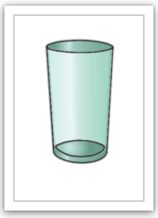
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109.bmp


110.bmp

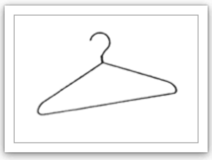

111.bmp


112.bmp


113.bmp


114.bmp


115.bmp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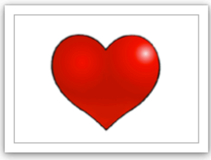
117.bmp


118.bmp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120.bmp


121.bmp

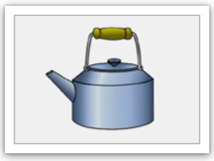

122.bmp


123.bmp


124.bmp


125.bmp


126.bmp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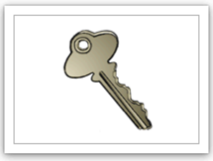
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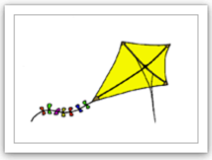
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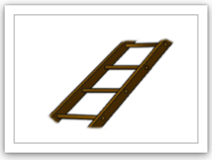
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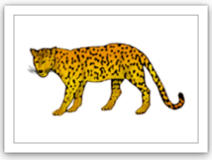
133.bmp


134.bmp


135.bmp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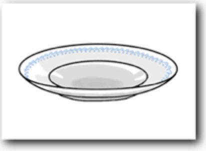

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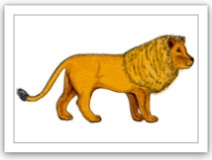
138.bmp

139.bmp



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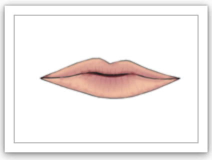

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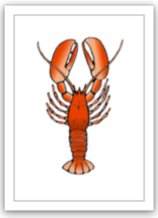

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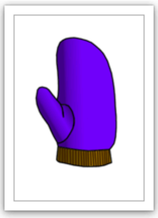

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146.bmp

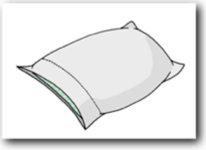
147.bmp

148.bmp

149.bmp

150.bmp

151.bmp

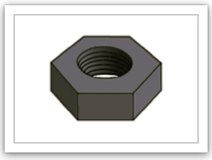


152.bmp

153.bmp

154.bmp

155.bmp



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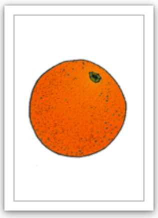
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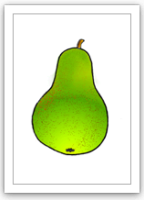
161.bmp


162.bmp


163.bmp


164.bmp


165.bmp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168.bmp


169.bmp


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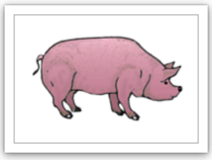
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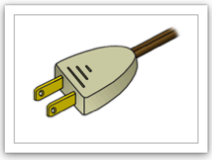
174.bmp


175.bmp


176.bmp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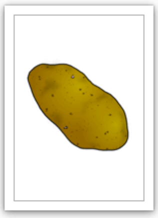
178.bmp


179.bmp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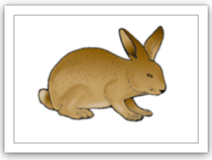
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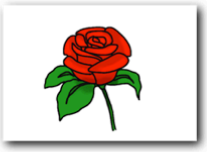
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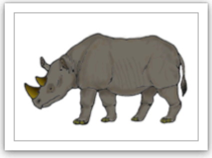
185.bmp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187.bmp


188.bmp


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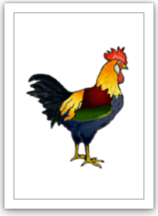
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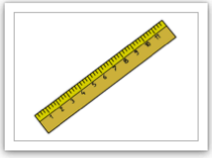
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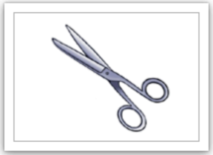
193.bmp


194.bmp


195.bmp


196.bmp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199.bmp


200.bmp


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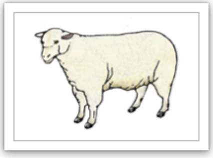
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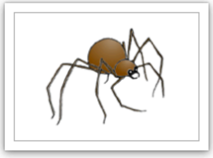
207.bmp


208.bmp


209.bmp


210.bmp


211.bmp


212.bmp

Appendix B


213.bmp


214.bmp

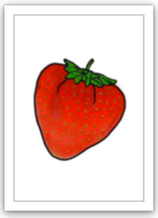

215.bmp


216.bmp


217.bmp


218.bmp


219.bmp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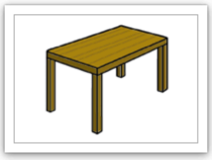
222.bmp


223.bmp


224.bmp


225.bmp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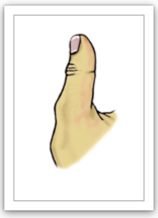
227.bmp


228.bmp


229.bmp


230.bmp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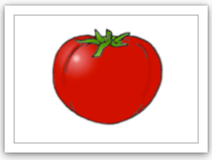
232.bmp


233.bmp


234.bmp


235.bmp


236.bmp

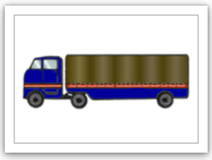

237.bmp


238.bmp


239.bmp

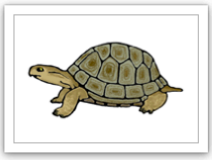

240.bmp

241.bmp



242.bmp

243.bmp



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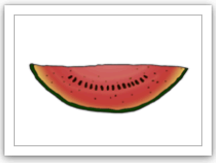
248.bmp

249.bmp

250.bmp

251.bmp



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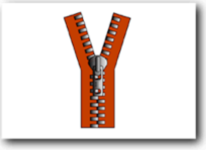
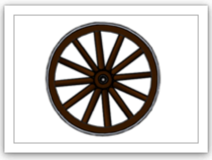


253.bmp



254.bmp

255.bmp

256.bmp

257.bmp

258.bmp

259.bmp

260.bmp

Appendix C

Word stimuli for Experiment 2 and their matched pictures.

Picture	Related word	Unrelated word	Picture	Related word	Unrelated word
Accordion	harp	zebra	Aeroplane	helicopter	lobster
Crocodile	dragon	sock	Stamp	photograph	camel
Ant	spider	volcano	Apple	pear	skunk
Arm	leg	lily	Arrow	bullet	blanket
Basketball	football	gorilla	Ashtray	bin	parrot
Bridge	road	pan	Axe	hammer	worm
Boat	ship	harp	Ball	globe	key
Balloon	kite	sheep	Banana	orange	mop
Computer	laptop	pancake	Barrel	pail	peach
Bat	racket	pianist	Basket	bag	necktie
Bear	wolf	pipe	Bed	sofa	flute
Bee	fly	accordion	Fire	stove	trumpet
Bell	gong	laptop	Belt	trousers	grasshopper
Bicycle	motorcycle	nose	Bird	duck	planet
Blouse	jacket	pail	Book	magazine	cucumber
Boot	sandal	tiger	Bottle	jar	wolf
Bow	belt	canoe	Bowl	plate	kangaroo
Box	sack	dragon	Bread	pancake	helicopter
Broom	mop	strawberry	Brush	comb	spinach
Bus	train	racket	Butterfly	grasshopper	sandal
Button	zip	axe	Cake	pie	needle
Camel	horse	screw	Candle	lantern	bean
Letter	list	chick	Cap	helmet	onion
Car	lorry	fish	Carrot	tomato	elephant
Cat	dog	lantern	Caterpillar	worm	ship
Celery	spinach	ashtray	Chain	rope	moon
Chair	bench	penguin	Cherry	strawberry	castle
Chicken	owl	earrings	Panda	gorilla	drawer
Church	school	sauce	Road	bridge	sack
Cigarette	pipe	raincoat	Clock	watch	zip
Bone	blood	lorry	Cloud	star	scissors
Clown	doll	teapot	Coat	vest	fly
Comb	brush	pumpkin	Corn	cucumber	switch
Sofa	bed	blood	Cow	sheep	ball
Crown	hat	road	Cup	glass	goat
Deer	fox	stairs	Desk	board	squirrel
Dog	cat	candle	Doll	puppet	fork
Donkey	pig	cigarette	Door	gate	tomato
Crab	lobster	pin	Dress	skirt	compass
Drawers	shelf	panda	Drum	trumpet	rabbit
Duck	hen	collar	Eagle	chick	toothpaste
Ear	nose	sofa	Elephant	kangaroo	slipper
Envelope	card	lightbulb	Eye	lips	belt
Fence	wall	leg	Finger	thumb	whale
Fish	tortoise	motorcycle	Flag	badge	donkey
Flower	mushroom	battery	Flute	accordion	orange
Fly	bee	screwdriver	Foot	hand	kettle

Appendix C

Picture	Related word	Unrelated word	Picture	Related word	Unrelated word
Globe	planet	dog	Helmet	cap	Giraffe
Fork	spoon	window	Fox	deer	pump
Lantern	candle	cabbage	Frog	fish	globe
Frying pan	kettle	mask	Bin	ashtray	cherry
Giraffe	zebra	tongs	glass	cup	crab
Glasses	telescope	cat	Glove	sock	snail
Goat	lamb	door	Gorilla	panda	football
Grapes	peach	lock	Grasshopper	butterfly	thumb
Guitar	piano	watermelon	Gun	cannon	mushroom
Hair	bone	bullet	Hammer	axe	lemon
Hand	foot	list	Hanger	iron	grapes
Bookshelf	drawer	duck	Hat	crown	frog
Heart	pump	drill	Helicopter	aeroplane	button
Horse	camel	desk	House	tent	crocodile
Iron	hanger	eagle	Ironing board	table	cloud
Jacket	blouse	toast	Kangaroo	elephant	pencil
Kettle	pan	piano	Key	lock	potato
Kite	balloon	vest	Knife	scissors	drum
Ladder	stairs	gun	Lamp	torch	telescope
Leaf	flower	helmet	Leg	arm	slide
Rope	chain	pear	Leopard	tiger	radio
Plate	bowl	suit	Lightbulb	battery	pig
Switch	lightbulb	pig	Lion	leopard	cupboard
Lips	eye	stove	Lobster	crab	bed
Lock	key	skirt	Mitten	scarf	ruler
Monkey	skunk	cannon	Moon	sun	wrist
Motorcycle	bicycle	apple	Mountain	volcano	necklace
Mouse	squirrel	nail	Mushroom	leaf	pot
Nail	screw	butterfly	Pillow	blanket	typre
Necklace	earrings	lamb	Needle	pin	statue
Nose	ear	bicycle	Nut	screwdriver	dress
Onion	pumpkin	boot	Orange	banana	cub
Ostrich	chicken	clock	Owl	eagle	tent
Paintbrush	pencil	seal	Trousers	necktie	carrot
Peach	grapes	saw	Peacock	swan	trousers
Peanut	bean	iron	Pear	apple	chain
Pen	paintbrush	spider	Pencil	ruler	snake
Penguin	seal	hammer	Pepper	cabbage	horn
Piano	guitar	deer	Pig	donkey	scarf
Pineapple	watermelon	bus	Pipe	cigarette	leopard
Jug	bottle	eye	Pliers	tongs	leaf
Plug	switch	flower	Handbag	basket	puppet
Dragon	crocodile	card	Potato	carrot	glass
Pumpkin	onion	badge	Rabbit	raccoon	torch
Raccoon	rabbit	plate	Rose	lily	bin
Refrigerator	cupboard	jacket	Rhinoceros	cow	magazine
Ring	necklace	train	Rocking chair	couch	fox
Rollerskate	slipper	paintbrush	Shark	whale	guitar
Rooster	parrot	handbag	Ruler	pen	ant
Sailboat	canoe	raccoon	Salt	sauce	kite
Sandwich	toast	crown	Mirror	window	pie
Scissors	knife	mouse	Screw	nail	ear

Appendix C

Picture	Related word	Unrelated word	Picture	Related word	Unrelated word
Screwdriver	drill	tortoise	Map	compass	banana
Seal	penguin	glove	Zebra	giraffe	rope
Sheep	goat	aeroplane	Shirt	sweater	chicken
Shoe	boot	lamp	Skirt	dress	knife
Skunk	monkey	hanger	Slippers	shoe	table
Snail	snake	jug	Snake	snail	car
Snowman	statue	bottle	Sock	glove	fire
Spider	ant	balloon	Tent	house	swan
Baby	cub	oven	Spoon	fork	blouse
Squirrel	mouse	bell	Star	cloud	arm
Stool	desk	lips	Stove	fire	owl
Strawberry	cherry	bat	Suitcase	handbag	bone
Sun	moon	comb	Swan	peacock	shelf
Sweater	shirt	cow	Swing	slide	bowl
Table	chair	peacock	Telephone	bell	sun
Television	radio	barrel	Tennis racket	bat	photograph
Thimble	needle	horse	Thumb	wrist	basket
Necktie	collar	house	Tiger	lion	board
Toaster	oven	bag	Bomb	gun	spoon
Tomato	potato	wall	Toothbrush	toothpaste	bee
Top	ball	shoe	Traffic light	lamp	hen
Truck	car	couch	Trumpet	drum	bush
Tortoise	frog	cap	Umbrella	raincoat	gong
Vase	pot	brush	Vest	suit	bridge
Violin	flute	sweater	Ghost	mask	cup
Watch	clock	lion	Watering can	teapot	star
Watermelon	lemon	foot	Zipper	button	school
Wheel	tyre	hat	Whistle	horn	chair
Windmill	castle	shirt	Window	door	bench
Wine glass	jug	gate	Wrench	saw	watch

Appendix D

Picture stimuli used in Experiments 2, 3A, 3B, and 4 with more than one accepted response in English or Mandarin. Mandarin characters are in parentheses.

Picture stimuli names in English and Mandarin	Accepted names for picture stimuli in English and Mandarin
Air plane	aeroplane, plane
fei ji (飞机)	-
Alligator	crocodile
shou feng qin (手风琴)	-
Ashtray	ball
yan hui gang (烟灰缸)	*yan die* (烟碟)
Baby	-
bao bao (宝宝)	*xiao hai* (小孩), *ying hai* (婴孩), *ying er* (婴儿)
Basketball	ball
lan qiu (篮球)	*qiu* (球)
Barrel	-
mu tong (木桶)	*tong zi* (桶子), *tong* (桶)
Bat	baseball bat
qiu bang (球棒)	*bang qiu pai* (棒球拍), *bang qiu gun* (球棍), *bang qiu bang* (棒球棒)
Bell	baseball bat
ling (铃)	*ling dang* (铃铛)
Belt	-
pi dai (皮带)	*ku dai* (裤带), *yao dai* (腰带)
Bicycle	bike
zi xing che (自行车)	*jiao che* (脚车)
Bin	dustbin, trash bin, rubbish bin, trashcan
la ji tong (垃圾桶)	-
Bird	-
xiao niao (小鸟)	*niao* (鸟)
Blouse	shirt
shang yi, (上衣)	*chen yi* (衬衣), *chen shan* (衬衫)
Boat	rowboat
chuan (船)	-

Bookshelf *shu jia* (书架)	rack, shelf *shu gui* (书柜), *xie jia* (鞋架)
Boot *xue zi* (靴子)	shoe *pi xie* (皮鞋), *xue xie* (靴鞋), *xie zi* (鞋子)
Bottle *ping zi* (瓶子)	- *bo li ping* (玻璃瓶), *ping* (瓶), *jiu ping* (酒瓶)
Bow *hu die jie* (蝴蝶结)	Ribbon -
Box *he zi* (盒子)	- *xiang zi* (箱子)
Bus *gong che* (公车)	- *xiao che* (校车), *ba shi* (巴士)
Button *niu kou* (纽扣)	- *kou* (扣), *kou zi* (扣子)
Cap *mao zi* (帽子)	hat, beret *mao* (帽)
Caterpillar *mao chong* (毛虫)	- *mao mao chong* (毛毛虫)
Capsicum *qing jiao* (青椒)	pepper *lv jiao* (绿椒), *jiao* (椒), *deng long jiao* (灯笼椒), *deng long la jiao* (灯笼辣椒)
Celery *qin cai* (芹菜)	vegetable, veg, spinach *shu cai* (蔬菜), *qing cai* (青菜), *cai* (菜)
Chain *tie lian* (铁链)	- *suo lian* (锁链), *lian zi* (链子), *lian* (链)
Cherry *yingtao* (樱桃)	plum -
Chicken *ji* (鸡)	hen *mu ji* (母鸡)
Church *jiao tang* (教堂)	chapel -
Cigarette *yan* (烟)	- *xiang yan* (香烟)
Clock *zhong* (钟)	- *nao zhong* (闹钟), *shi zhong* (时钟)

Coat *da yi* (大衣)	trench coat, overcoat, raincoat, lab coat *wai tao* (外套)
Corn *yu mi* (玉米)	maize *yu shu shu* (玉蜀黍)
Cow *niu* (牛)	buffalo *shui niu* (水牛)
Crown *huang guan* (皇冠)	- *tou guan* (头冠)
Deer *lu* (鹿)	reindeer, elk, antelope -
Desk *shu zhuo* (书桌)	table *zhuo zi* (桌子)
Dog *gou* (狗)	puppy -
Doll *wa wa* (娃娃)	girl *nv hai* (女孩), *nv hai zi* (女孩子), *wan ju wa wa* (玩具娃娃)
Donkey *lv* (驴)	mule -
Drawers *chou ti* (抽屉)	chest, cabinet *chu gui* (橱柜), *yi chu* (衣橱), *gui zi* (柜子), *yi gui* (衣柜), *chu zi* (橱子), *chu* (橱)
Dress *lian yi qun* (连衣裙)	- *lian shen qun* (连身裙)
Drum *gu* (鼓)	kettledrum *luo gu* (锣鼓)
Duck *ya zi* (鸭子)	goose, geese -
Eagle *ying* (鹰)	hawk -
Ear *er duo* (耳朵)	- *er* (耳)
Elephant *xiang* (象)	- *da xiang* (大象)
Envelope *xin feng* (信封)	letter *xin* (信)

Eye	-
yan jing (眼睛)	*yan* (眼)
Fence	-
zha lan (栅栏)	*mu zha* (木栅), *zha* (栅), *lan gan* (栏杆), *wei qiang* (围墙), *li ba* (篱笆), *wei lan* (围栏)
Finger	-
shi zhi (食指)	*shou zhi* (手指)
Fire	flame
huo, (火)	-
Flag	-
qi (旗)	*guo qi* (国旗)
Flute	clarinet, recorder
di zi (笛子)	*hei guan* (黑管), *chang di* (长笛), *di* (笛), *chui xiao* (吹箫)
Fly	housefly, bee
cang ying (苍蝇)	*mi feng* (蜜蜂)
Frog	-
qing wa (青蛙)	*tian ji* (田鸡)
Frying pan	-
ping di guo (平底锅)	*deng* (灯)
Glass	cup
bei zi (杯子)	*shui bei* (水杯), *bei* (杯)
Glasses	spectacles, specs
yan jing (眼睛)	-
Globe	earth
di qiu yi (地球仪)	*di qiu* (地球)
Gorilla	ape, orangutan
xing xing (猩猩)	-
Grasshopper	cricket
zha meng (蚱蜢)	*cao meng* (草蜢), *huang chong* (蝗虫), *xi shuai* (蟋蟀)
Gun	pistol
qiang (枪)	*shou qiang* (手枪)
Handbag	bag, purse bag
shou ti bao (手提包)	*ti bao* (提包), *bao* (包), *bao bao* (包包), *shu bao* (书包), *pi bao* (皮包)
Hanger	clotheshanger
yi jia (衣架)	-

Heart *xin* (心)	heart shape -
Helicopter *zhi sheng ji* (直升机)	- *zhi sheng fei ji* (直升飞机)
House *fang zi* (房子)	- *wu zi* (屋子)
Iron *yun dou* (熨斗)	- *yun dou qi* (熨斗器), *tang yi dou* (烫衣斗), *tang dou* (烫斗)
Ironing board *tang yi ban* (烫衣板)	- *tang yi jia* (烫衣架), *yun yi jia* (熨衣架), *yun ban* (熨板), *tang ban* (烫板), *tang dou ban* (烫斗板)
Jacket *wai tao* (外套)	coat *shang yi* (上衣), *da yi* (大衣)
Jug *shui hu* (水壶)	pitcher, flask *shui ping* (水瓶)
Kettle *zhu shui hu* (煮水壶)	- *cha hu* (茶壶), *re shui hu* (热水壶), *hu* (壶), *shui hu* (水壶)
Key *yao shi* (钥匙)	- *suo shi* (琐匙)
Knife *dao* (刀)	butter knife -
Ladder *ti zi* (梯子)	- *jie ti* (阶梯)
Lamp *tai deng* (台灯)	table lamp, desk lamp *deng* (灯), *zhuo deng* (桌灯)
Lantern *deng long* (灯笼)	lamp *deng* (灯)
Leaf *shu ye* (树叶)	maple leaf *feng ye* (枫叶), *ye zi* (叶子)
Leg *tui* (腿)	 *jiao* (脚)
Leopard *bao zi* (豹子)	cheetah, jaguar -
Letter *xin* (信)	paper *zhi* (纸)

Light bulb *deng pao* (灯泡)	bulb *dian deng pao* (电灯泡)
Lips *zui chun* (嘴唇)	mouth *kou* (口), *chun* (唇), *zui ba* (嘴巴)
Lobster *long xia* (龙虾)	crayfish -
Lock *suo tou* (锁头)	padlock *suo zi* (锁子)
Lorry *ka che* (卡车)	truck *huo che* (货车), *luo li* (罗李)
Mitten *shou tao* (手套)	glove, mitt -
Monkey *hou zi* (猴子)	ape *hou* (猴)
Moon *yue liang* (月亮)	- *yue* (月), *xin yue* (新月)
Motorcycle *dian dan che* (电单车)	motorbike *mo duo che* (摩托车)
Mountain *shan* (山)	- *shan ding* (山顶)
Mouse *lao shu* (老鼠)	rat, mice -
Mushroom *mo gu* (蘑菇)	- *gu* (菇)
Necklace *xiang lian* (项链)	pearls *zhu zi* (珠子)
Necktie *ling dai* (领带)	tie -
Orange *cheng* (橙)	- *cheng zi* (橙子)
Ostrich *tuo niao* (鸵鸟)	- *he* (鹤)
Paintbrush *mao bi* (毛笔)	brush *hua bi* (画笔)

Peach	apricot, plum
tao zi (桃子)	*mei* (梅), *mei zi* (梅子)
Peanut	nut, groundnut
hua sheng (花生)	-
Pear	-
li (梨)	*li zi* (梨子)
Pen	-
yuan zhu bi (圆珠笔)	*gang bi* (钢笔), *bi* (笔)
Pineapple	-
huang li (黄梨)	*bo luo* (菠萝), *feng li* (凤梨)
Plate	dish, saucer
pan zi (盘子)	*die zi* (碟子), *pan* (盘)
Plug	power plug
cha tou (插头)	*dian cha tou* (电插头)
Potato	-
tu dou (土豆)	*shu* (薯), *di gua* (地瓜), *fan shu* (番薯), *ma ling shu* (马铃薯)
Pumpkin	-
nan gua (南瓜)	*jing gua* (金瓜)
Rabbit	bunny
tu zi (兔子)	-
Refrigerator	fridge
bing xing (冰箱)	*bing chu* (冰橱)
Rhinoceros	rhino
xi niu (犀牛)	-
Ring	diamond ring
jie zhi (戒指)	-
Rocking chair	chair
yao yi (摇椅)	*yao bai yi* (摇摆椅)
Roller skates	rollerblade, skates
lun xie (轮鞋)	*hua lun xie* (滑轮鞋), *lun hua xie* (轮滑鞋)
Rope	cord, line
sheng zi (绳子)	*sheng* (绳)
Rose	flower
mei gui (玫瑰)	*hua* (花)
Shark	-

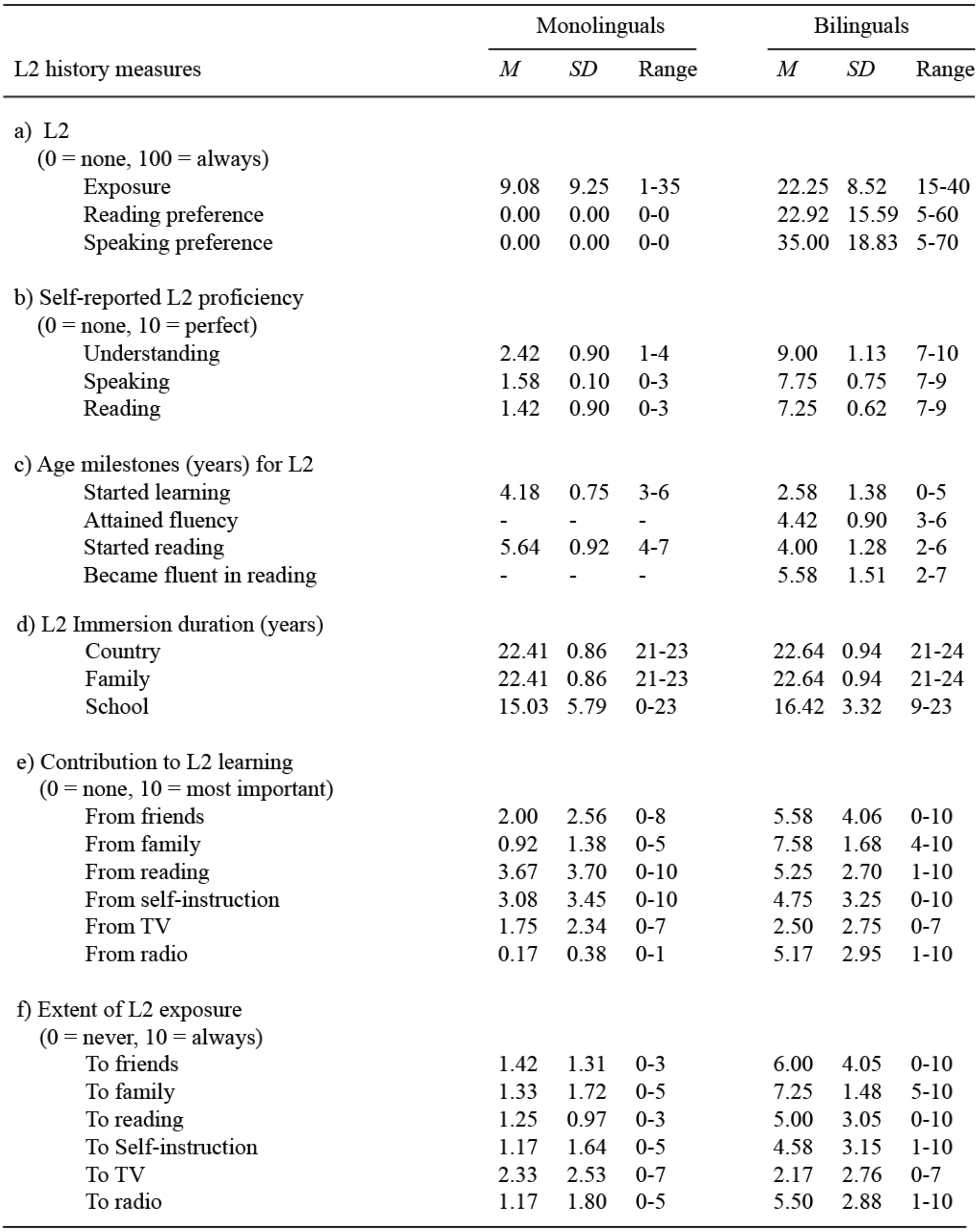
sha yu (鲨鱼)	*da bai sha* (大白鲨)
Rooster *gong ji* (公鸡)	chicken *ji* (鸡)
Road *gong lu* (公路)	- *ma lu* (马路), *lu* (路)
Ruler *chi zi* (尺子)	- *chi* (尺)
Sailboat *fan chuan* (帆船)	yacht, boat *chuan* (船)
Salt *yan* (盐)	pepper, peppershaker, shaker *hu jiao fen* (胡椒粉), *hu jiao guan* (胡椒罐)
Sandwich *san ming zhi* (三明治)	*san wen zhi* (三文治)
Scissors *jiao dao* (剪刀)	*jian zi* (剪子)
Screw *luo si ding* (螺丝钉)	nut *luo si* (螺丝)
Screwdriver *luo si dao* (螺丝刀)	- *qi zi* (起子), *luo si qi zi* (螺丝起子)
Seal *hai bao* (海豹)	sealion, walrus *hai xiang* (海象), *hai shi* (海狮)
Sheep *mian yang* (绵羊)	- *yang* (羊)
Shirt *chen shan* (衬衫)	blouse *shang yi* (上衣)
Skirt *qun zi* (裙子)	- *chang qun* (长裙), *qun* (裙)
Skunk *chou you* (臭鼬)	- *chou shu* (臭鼠)
Slippers *tuo xie* (拖鞋)	flipflops -
Sock *wa zi* (袜子)	- *wa* (袜)
Sofa *sha fa* (沙发)	couch -

Spoon	-
shao zi (勺子)	*shao* (勺)
Star	-
xing xing (星星)	*xing* (星)
Stove	oven
lu zao (炉灶)	*mei qi lu* (煤气炉), *lu zi* (炉子), *lu* (炉), *hong lu* (烘炉), *dian lu* (电炉)
Suitcase	case, briefcase, luggage, luggage bag
pi xiang (皮箱)	*gong shi bao* (公事包), *shu bao* (书包), *xing li xiang* (行李箱), *shu ti bao* (手提包), *lv xing xiang* (旅行箱)
Swan	-
e (鹅)	*tian e* (天鹅)
Table	desk
zhuo zi (桌子)	-
Telephone	phone
dian hua (电话)	-
Television	TV
dian shi (电视)	*dian shi ji* (电视机)
Tennis racket	badminton racket, racket
yu wang qiu pai (与网球拍)	*qiu pai* (球拍)
Tent	-
zhang peng (帐篷)	*ying zhang* (营帐)
Thimble	bucket
ding zhen (顶针)	-
Thumb	-
mu zhi (拇指)	*da mu zhi* (大拇指)
Tiger	-
lao hu (老虎)	*hu* (虎)
Trousers	pants
ku zi (裤子)	-
Toaster	-
duo shi lu (多士炉)	*kao mian bao ji* (烤面包机)
Tomato	-
fan qie (番茄)	*xi hong shi* (西红柿)
Top	spinning top

tuo luo (陀螺)	-
Traffic light	-
hong lv deng (红绿灯)	*hong deng* (红灯), *qing hong deng* (请红灯), *jiao tong deng* (交通灯)
Train	-
huo che (火车)	*lie che* (列车), *tie che* (铁车)
Trumpet	trombone
xiao hao (小号)	*xiao la ba* (小喇叭), *la ba* (喇叭)
Tortoise	turtle
wu gui (乌龟)	*gui* (龟)
Vase	-
hua ping (花瓶)	*ping* (瓶), *ping zi* (瓶子)
Violin	cello
xiao ti qin (小提琴)	*da ti qin* (大提琴), *ti qin* (提琴)
Watch	-
shou biao (手表)	*biao* (表)
Watering can	water can
jiao shui hu (浇水壶)	*jiao hua tong* (浇花桶), *jiao shui guan* (浇水罐)
Wheel	-
lun zi (轮子)	*lun* (轮)
Whistle	-
shao zi (哨子)	*kou shao* (口哨)
Window	-
chuang hu (窗户)	*chuang kou* (窗口)
Wine glass	glass, cup
jiu bei (酒杯)	*bo li bei* (玻璃杯), *bei* (杯), *bei zi* (杯子)
Wrench	spanner
ban shou (扳手)	*ban zi* (板子)
Zipper	zip
la lian (拉链)	*la suo* (拉锁)

Appendix E

Participant information for Experiment 1.



	Monolinguals			Bilinguals		
L2 history measures	*M*	*SD*	Range	*M*	*SD*	Range
a) L2						
(0 = none, 100 = always)						
Exposure	9.08	9.25	1-35	22.25	8.52	15-40
Reading preference	0.00	0.00	0-0	22.92	15.59	5-60
Speaking preference	0.00	0.00	0-0	35.00	18.83	5-70
b) Self-reported L2 proficiency						
(0 = none, 10 = perfect)						
Understanding	2.42	0.90	1-4	9.00	1.13	7-10
Speaking	1.58	0.10	0-3	7.75	0.75	7-9
Reading	1.42	0.90	0-3	7.25	0.62	7-9
c) Age milestones (years) for L2						
Started learning	4.18	0.75	3-6	2.58	1.38	0-5
Attained fluency	-	-	-	4.42	0.90	3-6
Started reading	5.64	0.92	4-7	4.00	1.28	2-6
Became fluent in reading	-	-	-	5.58	1.51	2-7
d) L2 Immersion duration (years)						
Country	22.41	0.86	21-23	22.64	0.94	21-24
Family	22.41	0.86	21-23	22.64	0.94	21-24
School	15.03	5.79	0-23	16.42	3.32	9-23
e) Contribution to L2 learning						
(0 = none, 10 = most important)						
From friends	2.00	2.56	0-8	5.58	4.06	0-10
From family	0.92	1.38	0-5	7.58	1.68	4-10
From reading	3.67	3.70	0-10	5.25	2.70	1-10
From self-instruction	3.08	3.45	0-10	4.75	3.25	0-10
From TV	1.75	2.34	0-7	2.50	2.75	0-7
From radio	0.17	0.38	0-1	5.17	2.95	1-10
f) Extent of L2 exposure						
(0 = never, 10 = always)						
To friends	1.42	1.31	0-3	6.00	4.05	0-10
To family	1.33	1.72	0-5	7.25	1.48	5-10
To reading	1.25	0.97	0-3	5.00	3.05	0-10
To Self-instruction	1.17	1.64	0-5	4.58	3.15	1-10
To TV	2.33	2.53	0-7	2.17	2.76	0-7
To radio	1.17	1.80	0-5	5.50	2.88	1-10

Appendix E

Participant information for Experiment 2.

	Monolinguals			Bilinguals		
L2 history measures	*M*	*SD*	Range	*M*	*SD*	Range
a) L2						
(0 = none, 100 = always)						
Exposure	7.00	4.47	1-15	24.33	11.90	15-50
Reading preference	0.00	0.00	0-0	15.42	18.14	0-50
Speaking preference	0.00	0.00	0-0	36.67	10.94	20-50
b) Self-reported L2 proficiency						
(0 = none, 10 = perfect)						
Understanding	2.83	1.27	1-5	8.50	0.90	7-10
Speaking	1.00	0.74	0-2	7.75	1.06	7-10
Reading	0.58	1.00	0-3	7.42	0.67	7-9
c) Age milestones (years) for L2						
Started learning	3.92	1.24	1-5	2.67	1.50	0-5
Attained fluency	-	-	-	4.67	0.78	4-6
Started reading	4.67	0.98	4-7	3.83	1.19	2-6
Became fluent in reading	-	-	-	6.42	0.90	5-8
d) L2 Immersion duration (years)						
Country	22.39	1.15	21-25	23.00	1.24	21-25
Family	22.39	1.15	21-25	23.00	1.24	21-25
School	19.33	3.41	15-24	17.85	3.42	15-25
e) Contribution to L2 learning						
(0 = none, 10 = most important)						
From friends	3.50	1,68	1-7	6.25	2.18	2-10
From family	1.67	2.39	0-7	8.08	2.19	2-10
From reading	2.75	2.70	0-8	5.67	2.02	1-8
From self-instruction	0.58	0.90	0-3	2.00	2.41	0-7
From TV	3.83	3.56	0-10	6.42	2.31	3-10
From radio	0.75	2.01	0-7	4.42	2.02	0-7
f) Extent of L2 exposure						
(0 = never, 10 = always)						
To friends	3.00	1.71	1-7	4.75	2.18	2-10
To family	1.67	2.10	0-7	8.08	2.12	2-10
To reading	1.58	2.15	0-7	2.42	2.54	0-9
To Self-instruction	1.00	1.91	0-5	0.42	0.51	0-1
To TV	3.42	3.55	0-10	5.00	2.92	1-10
To radio	1.00	2.04	0-7	3.17	2.08	0-7

Appendix E

Participant information for Experiment 3A and 3B.

	Balanced			Unbalanced		
L2 history measures	*M*	*SD*	Range	*M*	*SD*	Range
a) L2						
(0 = none, 100 = always)						
Exposure	25.58	10.60	15-45	16.00	5.08	12-30
Reading preference	9.13	2.28	2-10	0.19	0.38	0-1
Speaking preference	7.20	1.99	5-10	2.69	1.89	0-5
b) Self-reported L2 proficiency						
(0 = none, 10 = perfect)						
Understanding	8.17	1.19	7-10	6.92	1.16	4-8
Speaking	7.92	0.90	7-10	4.92	1.24	2-6
Reading	7.42	0.67	7-9	4.25	1.71	1-6
c) Age milestones (years) for L2						
Started learning	3.25	1.71	0-5	4.25	1.22	2-6
Attained fluency	6.83	2.12	4-12	6.25	3.08	3-13
Started reading	4.58	1.73	2-7	5.00	1.60	3-7
Became fluent in reading	7.50	2.75	2-12	7.58	2.93	3-13
d) L2 Immersion duration (years)						
Country	23.24	1.56	21-26	22.43	1.35	21-24
Family	23.24	1.56	21-26	21.51	3.84	10-24
School	19.51	3.34	14-25	16.97	6.87	2-24
e) Contribution to L2 learning						
(0 = none, 10 = most important)						
From friends	2.67	2.42	0-7	7.83	2.76	0-10
From family	8.17	1.03	6-10	5.08	1.68	2-7
From reading	8.58	1.62	5-10	4.92	2.31	1-8
From self-instruction	1.92	2.35	0-6	1.17	1.64	0-5
From TV	5.75	2.26	1-9	6.42	2.47	2-10
From radio	2.75	2.93	0-8	3.25	2.63	0-7
f) Extent of L2 exposure						
(0 = never, 10 = always)						
To friends	4.58	2.61	1-9	7.92	2.39	1-10
To family	9.08	1.00	7-10	4.00	2.00	1-7
To reading	9.50	0.67	8-10	1.67	1.37	0-4
To Self-instruction	6.00	2.63	0-10	2.17	2.33	0-6
To TV	3.67	3.85	0-10	1.75	2.96	0-10
To radio	6.75	2.38	3-10	4.67	3.08	0-10

Appendix E

Participant information for Experiment 4.

	Balanced			Unbalanced		
L2 history measures	*M*	*SD*	Range	*M*	*SD*	Range
a) L2 (0 = none, 100 = always)						
Exposure	22.17	4.39	15-30	15.67	3.87	11-23
Reading preference	7.28	2.20	4-10	3.83	1.70	1-6
Speaking preference	6.88	1.85	4-10	3.08	1.55	1-5
b) Self-reported L2 proficiency (0 = none, 10 = perfect)						
Understanding	8.58	1.17	6-10	7.83	1.11	7-10
Speaking	7.83	0.83	7-9	4.75	1.06	3-6
Reading	7.25	0.45	7-8	3.67	1.61	0-5
c) Age milestones (years) for L2						
Started learning	3.08	1.56	0-5	3.92	0.67	3-5
Attained fluency	5.42	0.90	4-7	8.67	4.03	3-15
Started reading	4.33	1.07	3-7	5.75	3.05	1-13
Became fluent in reading	7.08	1.24	4-9	11.08	2.71	8-18
d) L2 Immersion duration (years)						
Country	22.22	1.09	21-24	22.31	1.09	21-24
Family	17.48	8.94	0-24	22.31	1.09	21-24
School	14.10	4.50	6-21	13.29	6.54	2-22
e) Contribution to L2 learning (0 = none, 10 = most important)						
From friends	6.50	3.45	0-10	3.92	4.25	0-10
From family	8.50	1.45	6-10	7.08	1.78	4-10
From reading	7.58	1.93	5-10	6.08	1.56	4-10
From self-instruction	3.50	2.28	1-7	4.67	2.53	0-8
From TV	4.08	2.81	0-8	4.50	2.91	0-8
From radio	6.92	1.51	4-9	6.58	2.68	3-10
f) Extent of L2 exposure (0 = never, 10 = always)						
To friends	6.00	3.57	0-10	3.67	4.21	0-10
To family	8.92	0.79	8-10	5.50	2.35	2-10
To reading	7.33	2.39	4-10	4.42	2.68	1-9
To Self-instruction	5.33	2.35	2-9	5.67	2.71	1-10
To TV	2.67	3.11	0-10	3.25	3.49	0-10
To radio	5.08	2.47	2-9	6.16	2.72	3-10