

ABSTRACT

Title of Dissertation: MIX AND SWITCH EFFECTS IN BILINGUAL
LANGUAGE PROCESSING

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This study utilized a novel task design in an effort to identify the source of the second language processing advantage commonly reported in mixed language conditions, investigate switch cost asymmetry in non-balanced bilinguals, and identify task-related variables that potentially contribute to inconsistent results across studies with similar participant populations. Seventy highly-proficient Korean-English bilinguals completed modified picture naming, semantic categorization, and lexical decision tasks, as well as a cognitive control task designed to examine the potential relationship between lexical control and general cognitive control. While no significant relationship was found between lexical control and general cognitive control, several key task-related variables emerged with respect to mix and switch effects. Specifically, verbal production requirements and increased second language repetition effects significantly influenced results. Furthermore, this study revealed potential effects of semantic load as well as script differences in receptive tasks. Results from this study highlight several key variables that contribute to bilingual mix and switch effects, as well as task design-related considerations for future bilingual mix and switch studies.

MIX AND SWITCH EFFECTS IN BILINGUAL LANGUAGE PROCESSING

by

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1 Introduction

1.1 Purpose

The primary purpose of this dissertation research is to investigate reported effects of language mixing and switching on processing by bilingual speakers in an attempt to clarify the origin of the effects and better understand implications for Second Language Acquisition theory and aptitude testing. In this chapter, concepts central to this project will be introduced, shortcomings in the extant literature will be identified, and the study's intended contribution to the field of Second Language Acquisition will be detailed. Finally, an overview of the study, research focus, and empirical tasks will be presented and discussed.

1.2 Key Concepts and Research Foci

1.2.1 The Mental Lexicon and Lexical Selection

The organization of the mental lexicon is of great interest to researchers in the fields of Psycholinguistics and Second Language Acquisition. By examining how lexical items are stored, researchers attempt to better understand how languages are processed, as well as how they are learned and maintained. However, determining how representations are stored and organized in the mind and concretely identifying the processes underlying lexical access and selection has proven to be a formidable challenge. This is particularly true for the study of the bilingual lexicon as the existence of an additional language system (or systems) further complicates the selection of target lexical items. In this case, a key question becomes how the lexicon is organized and how multilingual individuals manage to select and utilize one language in the face of another (sometimes more

dominant) language. Furthermore, as past research in this area strongly suggests that one language cannot simply be “turned off” in favor of another (e.g., Colome, 2001; Hermans, Bongaerts, de Bot, & Schreuder, 1999; Kroll, Sumutka, & Schwartz, 2005; Van Hell & Dijkstra, 2002; Van Heuven, Dijkstra, & Grainger, 1998), some sort of control mechanism is required to explain how activation and selection of target words occurs.

As will be discussed in Chapter 2, research into the organization of the bilingual lexicon has raised key questions regarding the degree of overlap (or separation) between languages in the bilingual mind, how target words are selected at the expense of their competitors, and the locus of selection (i.e., at what point in the processing of language does selection actually occur). Several experimental tasks have been utilized to explore these questions, with a variety of switch tasks used in attempts to define the mechanism(s) and locus of lexical selection. As will be reviewed in Chapter 3, the linguistic task switch literature is both extensive and controversial. There is, as yet, no consensus on a number of key points, including the critical questions of how and when selection of target lexical items actually occurs along the time course of bilingual language processing. The ongoing debate in the literature centers on several key points, including: the degree of integration or separation between a bilingual’s lexical stores, the bilingual’s ability (or lack of ability) to selectively activate and select words from only one lexicon, the time course of selection, and, critically, the actual mechanism that enables selection. Regarding the mechanism of selection, a central focus of current debates is the need for inhibition of the non-target language to effectively select a target language competitor. A large portion of the linguistic task switch literature focuses on this topic, and results and conclusions vary. In an attempt to add a degree of clarity to this

issue, this research project will focus on two interesting phenomena commonly associated with linguistic task switching tasks, mix and switch effects.

1.2.2 Language Mix and Switch Effects

Mix effects are commonly observed during bilingual language production tasks, such as picture or digit naming, when more than one response language is required during a single block. Generally, when naming pictures using only the dominant first language (L1), bilinguals show a reaction time advantage compared to single language L2 picture naming (e.g., Christoffels et al., 2006; Kroll, Michael, Tokowicz, and Dufour, 2002). However, an interesting change occurs in blocks that require responses in both languages (i.e., mixed condition); first language responses are often slower than L2 responses (e.g., Phillip, Gade, & Koch, 2006). More specifically, an L2 processing advantage appears to arise in conjunction with an apparent L1 disadvantage in mixed picture naming conditions. While the exact cause of the L2 advantage is unknown, inhibition-related effects and lexicalization bias have been proposed.

In addition to mix effects, another major focus in the linguistic task switch literature is switch costs, which refers to processing costs resulting from switching from one response language to another (e.g., naming a picture using L1, and then the next picture in L2). In a seminal study, Meuter & Allport (1999) found asymmetric switch costs for low proficiency bilinguals, with switches into their native language taking longer than switches into their weaker second language. Despite more than a decade of research following Meuter & Allport's (1999) language switch study, several critical questions remain regarding the origin and consistency of the study's central finding. Several studies

have replicated the finding of asymmetric switch costs for low-proficiency learners as well as extended the findings to include symmetrical switch costs for balanced bilinguals (e.g., Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Schwieter & Sunderman, 2008). However, a number of recent, similar studies failed to replicate these basic findings (e.g., Finkbeiner, Almeida, Janssen, & Caramazza, 2006; Gollan & Ferreira, 2009), and criticism has been leveled toward traditional picture and digit naming switch studies on methodological grounds (e.g., Finkbeiner et al., 2006).

Mix and switch effects have been studied extensively in an effort to better understand the organization of the bilingual lexicon, lexical access, and the mechanism(s) responsible for language selection. One common theme that has tied mix costs, switch costs, and switch mechanisms together in the literature is that of inhibitory control. Several recent studies (e.g., Costa & Santesteban, 2004, Costa, Santesteban, & Ivanova, 2006; Meuter & Allport, 1999; Schwieter & Sunderman, 2008) have provided evidence that inhibitory control plays a role in suppressing non-target language items during bilingual processing. Findings from these studies have been used as supporting evidence for Green's (1986; 1998) Inhibitory Control theory, which claims that a bilingual's non-target language must be inhibited, or suppressed, in order for lexical selection to occur in the target language.

Mix and Switch cost studies carry implications for both the Psycholinguistics and Second Language Acquisition fields. Not only does language switching data inform investigations into bilingual lexical control and selection, this research also carries implications for more traditional targets of SLA research such as second language learning aptitude and aptitude testing. For example, based on bilingual picture naming

reaction time experiments common in psycholinguistics research (e.g., Kroll & Stewart, 1994; Levy et al., 2007; Meuter & Allport, 1999), Costa and colleagues (Costa, 2005; Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006) claim that whereas inhibition is necessary for language control for lower proficiency bilinguals, experienced highly proficient and balanced bilinguals rely instead on attentional control that enables more top-down control of processing. Schwieter & Sunderman (2008) recently provided supporting evidence for Costa et al.'s (2006) proficiency-driven language control theory, and posited a point along the L2 proficiency continuum where the shift from inhibitory control to language-select processing occurs. If correct, the enhanced ability of balanced bilinguals to control language selection, as well as the shift from reactive inhibition to more top-down attentional control, carry potential implications for current second language learning aptitude theory and aptitude testing. If this processing shift does occur (and if lexical selection actually is a component of language aptitude), it would raise the possibility that second language learning aptitude is subject to change based on experience with foreign language learning and use. However, this notion of proficiency-driven aptitude change contradicts the SLA field's traditionally held concept of aptitude, which is viewed as generally stable, determined largely by genetics and early experience (see DeKeyser & Koeth, 2010), and not significantly affected by previous language learning experience (Carroll and Sapon, 1957). One key question is the nature of the proposed shift from reliance on inhibitory control to top-down (language select) control of bilingual language processing. A critical point is if processing changes are limited to the highly proficient L2 (e.g., Schwieter & Sunderman, 2008), or if the qualitative shift in control processes can be applied to weaker third and fourth languages (e.g., Costa &

Santesteban, 2004). As bilingual mix and switch tasks form the core measures used to investigate this issue, full understanding of task methodology and processes underlying bilingual language switch and mix performance is critical.

1.2.3 Unresolved Issues and Study Goals

Due to the relevance of mix and switch costs to basic psycholinguistic research and SLA theory, a closer examination of the underlying causes, mechanisms, and effects of mix and switch phenomena are warranted. Despite an extensive literature on the topic, several critical questions remain. Major issues yet to be resolved include: 1) the degree to which mix and switch phenomena (e.g., switch cost asymmetry) commonly found in production tasks occur in differing contexts, such as receptive tasks with variable semantic loads, 2) the source of the L2 advantage (and apparent L1 disadvantage) in bilingual picture naming mixed conditions, and 3) the locus of selection during bilingual language switches. Also of interest is the purported role of inhibitory control in lexical selection, as well as its potential role as aptitude for second language acquisition. Therefore, this research project has been developed to meet the following goals:

1. Replicate asymmetric switch costs and mixed-condition L2 advantage with Korean-English bilinguals performing a bilingual picture naming task.
2. Determine if the L2 reaction time advantage commonly found in mixed language picture naming blocks is a local effect (i.e., limited to the mixed block) or if the advantage carries over to subsequent single-language blocks.

3. Determine if the L2 advantage and switch costs are observed in a modified Go No-Go variant of the task that removes the requirement to verbally name the stimuli for one language.

4. Determine if the L2 advantage and switch cost asymmetry reported in bilingual picture naming tasks exist in receptive tasks. A standard lexical decision task (Korean and English) will be followed by a semantic categorization task in order to examine potential differences resulting from increased semantic load.

5. Provide preliminary evidence for whether the performance on linguistic mix and switch tasks is affected by non-linguistic inhibitory control ability. The purpose of this goal is to gather data for potential follow-up studies investigating inhibitory control as aptitude for second language acquisition

1.3 Contribution to SLA research

The study of the bilingual lexicon, including lexical access and selection, is a central focus of psycholinguistics research (e.g., Bialystok, Craik, & Luk, 2008; Costa, 2005; Costa, Miozzo, & Caramazza, 1998; Hartsuiker, Pickering, & Velkamp, 2004; Kroll, Bobb, Misra & Guo, 2008; La Heij, 2005). However, it also carries important implications for core issues in the field of Second Language Acquisition, such as how language processing changes as a function of proficiency along the time course of second language learning. In this regard, overlap between the fields of Psycholinguistics and Second Language Acquisition is clearly evident in psycholinguistics-based processing models such as Kroll and Stewart's (1994) Revised Hierarchical Model as well as a recent model of language control and lexical selection proposed by Costa and colleagues

(e.g., Costa, 2005; Costa and Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006). In the case of the Revised Hierarchical Model (Kroll and Stewart, 1994), connections between lexical items and concepts are said to vary based on the proficiency of the second language learner, with low-proficiency language learners forced to rely on L1 translation equivalents during L2 processing. The proposed developmental shift from L1-mediated processing to a more direct route available to high-proficiency learners is important for the study of second language acquisition for several reasons. Within the mental lexicon, the degree to which the second language is integrated with (or isolated from) the first language system, how second language learners control the non-target language, and how processing routes and language control ability might change over time, all carry implications for the processing of both languages over the course of second language acquisition.

Like the RHM, research by Costa et al. (e.g., Costa, 2005; Costa and Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006) on control mechanisms underlying bilingual lexical selection have direct implications for key topics in the field of SLA. Costa and Santesteban's (2004) proposed proficiency-driven shift from reliance on inhibitory control to more top-down, attentional control not only contributes to the understanding of how the bilingual lexicon is organized and accessed, it also raises interesting challenges to the conceptualization of aptitude as traditionally viewed in SLA. In an attempt to identify the source(s) of language control (i.e., how bilinguals are able to consistently speak in one language without unwanted intrusions from the non-target language), Costa and colleagues have proposed control mechanisms that change over time as a function of

increasing proficiency in the second language (Costa & Santesteban, 2004; Costa et al., 2006).

In addition to potential contributions to Second Language Acquisition theory, the examination of mix and switch costs has direct application to the ongoing development of second language aptitude test batteries. One example is the High Level Language Aptitude Battery (Hi-LAB) being developed at the University of Maryland Center for Advanced Study of Language (see Doughty et al., 2010), which includes measures of task switching ability and inhibitory control. Identifying the source of mix and switch costs, as well as the potential influence of individual differences in inhibitory control on second language acquisition, would contribute to a better understanding of how these tasks might relate to second language learning aptitude.

1.4 Current Study

Motivated by the potential importance of the control theories posited by Costa and colleagues (Costa, 2005; Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Costa et al., 2009) with respect to both bilingual language processing and second language learning aptitude, this study was designed to explore several key findings related to bilingual language control and language switch performance. More specifically, this study will utilize a picture naming task, a stop-and-go picture naming variant, lexical decision task, and a semantic categorization task in an attempt to better isolate and identify the source of L2 advantage in mixed naming conditions. In addition to the four critical switch tasks, a general cognitive control task (the Simon Task, Simon & Rudell, 1967), will be administered in an attempt to measure the potential relationship between

lexical access and selection and cognitive control as aptitude for second language learning and use.

The research questions for this project will be investigated through three separate experiments. Each of the three experiments will include one bilingual picture naming task, two receptive tasks, and one measure of general cognitive control.

Before details of the study are introduced, a literature review will be presented to outline current theories of language processing, bilingual processing models, and cognitive control as a potential mechanism for overcoming challenges unique to selection and activation of target words in the face of cross-language competitors. Chapter 2 introduces relevant bilingual language processing literature, followed by a detailed review of the task switching literature in Chapter 3. Chapter 4 presents literature on second language aptitude and discusses the potential relationship between language switching and cognitive control as language learning aptitude. Chapter 5 identifies critical questions left unanswered in the literature and reports on a recent pilot study that addressed several of the current study's key research questions. Chapter 6 introduces the current study and research questions, and Chapters 7, 8, and 9 detail the tasks, methods, and results for each of the study's three experiments. The General Discussion and Conclusion follow in Chapter 10.

2 Bilingual Language Processing

2.1. Lexical Selection

The activation of concepts and selection of appropriate lexical items in speech production has been the topic of intense debate and the focus of numerous theories (e.g., Dell, 1986; Levelt, 1992; Levelt, Roelofs, & Meyer, 1999). One basic assumption common to these theories is that the process of speech production first begins with the activation of an intended semantic representation or concept. In most models, this activation then spreads downward to corresponding representations at the lexical level (Levelt, 1989; 1992). Due to the potentially vast number of related lexical items receiving activation from this process, a mechanism is required by which the correct item can be selected for further processing. The exact manner in which this selection occurs has been the subject of fierce debate, but leading models (e.g., Levelt 1989) postulate a competition for selection based on the activation of a target node compared to the activation levels of its competitors. The Luce ratio (Luce, 1963) has been utilized to represent the activation of a target node in relation to its competitors. According to Luce, activation of a target node becomes more difficult and time consuming as the difference between the target and competing nodes decreases. In other words, it will take longer to activate a target node with several very similar competitors compared to a more unique node with no close competitors.

Identifying and detailing a mechanism responsible for selection between activated and potentially competing lexical nodes is a complex endeavor. However, the issue becomes more challenging when considering the addition of a second or third language system. This problem is further compounded by varying degrees of proficiency as well as

the fact that bilingual speakers may switch languages, sometimes frequently, depending on their linguistic environment and the language skill set of their interlocutors.

2.2. Bilingual Lexical Selection

The lexical competition inherent in L1 processing models is further complicated by the addition of one or more additional language systems. As emphasized by Grosjean (1998; 2001), bilinguals are not simply the sum of two monolingual systems. While few issues related to bilingual lexical organization and selection enjoy consensus among researchers in the field, the notion that bilinguals do not have the ability to completely shut off one language in favor of another is generally well accepted. Finkbeiner et al. (2006) summarize this view succinctly; “Today we know that the language switching hypothesis is wrong in its strongest form: language systems are not turned on and off” (p. 164). The concurrent activation of multiple language systems further complicates the selection of the intended lexical target for further processing. It is therefore not surprising that models of monolingual language processing do not map neatly onto that of bilinguals. While certain fundamental similarities exist, such as cascading activation from the semantic level down to the lexical level (Dell, 1986; Levelt, 1989; 1992), the existence of an additional language system may greatly increase the number of possible competitors for selection.

The existence of multiple language systems raises the critical question of whether languages are completely separate in the mind of a bilingual or if they overlap and interact. Early research into this question (Weinrich, 1968) identified three possible structures for the bilingual lexicon: the coordinate system, the compound system, and the

subordinate system. The first system, the coordinate system, maintains that the two languages of a bilingual speaker are completely separate, with each possessing its own word forms and meanings. In the compound system, word forms are organized separately according to language, but the two languages share access to the same conceptual system. Finally, the subordinate system is organized in such a way that the bilingual's weaker language is processed via the stronger first language.

The acquisition of a second language, and how it is connected to existing first language representations, was further explored by Potter, So, Von Eckardt, and Feldman (1984). Potter et al. examined two competing models, the word association model and the concept mediation model. The word association model proposed that second language lexical items are processed through direct connections with their L1 translation equivalents. In contrast, the concept mediation model posited that L2 meanings are tied directly to the meaning, or concept, of the word, with no need for mediation through the L1 translation. While Potter et al. (1984) provided initial support for the concept mediation model for all learners, later research would suggest that both models are plausible, and the routes by which L2 lexical items are processed depend heavily on proficiency.

Based on data from word naming, picture naming, and translation tasks, Kroll and colleagues (e.g., Kroll, Michael, Tokowicz, & Durour, 2002; Kroll & Stewart, 1994; Kroll & Tokowicz, 2001) posited a proficiency-driven developmental shift in second language processing in which learners progress from word association to concept mediation. In other words, while lower-proficiency second language learners tend to process second language lexical items via the corresponding L1 translation equivalents,

more advanced learners demonstrate a shift toward processing in which meaning can be accessed directly from L2 words (i.e., not mediated by L1 translation equivalents). The Revised Hierarchical Model (Kroll & Stewart, 1994) formally ties together Potter et al.'s (1984) word association and concept mediation models, and states that the strength of connections between L1 and L2 lexical items vary by proficiency. Based on this model, the initial dependence on L1 lexical items to mediate L2 processing for lower proficiency bilinguals creates strong lexical connections from the L2 to the L1. Lexical connections from the L1 to L2, however, are thought to be weaker because translations from L1 to L2 are processed via meanings and not directly from L1 to L2 words. Kroll & Stewart (1994) presented the translation performance of high-proficiency Dutch-English bilinguals as evidence, including slower translation time from L1 to L2 (concept mediated) than L2 to L1 (direct translation), and the absence of semantic effects when translating from the second language to the first. Scholl, Sankaranarayanan, and Kroll (1995) provided additional evidence of translation asymmetry during picture naming, which further strengthened the claims of the Revised Hierarchical Model.

In addition to establishing a proficiency-related bridge between the word association and concept mediation models, the Revised Hierarchical Model provides insight into the degree to which the second language is connected to the first. That is, the model is based on connections between the two languages and entails simultaneous activation of non-target language lexical items. More recent research on bilingual word recognition has provided further evidence that lexical items in both the target language and non-target language(s) receive activation during language production (e.g., Colomé,

2001; Costa, Miozzo, & Caramazza, 1999; Lee & Williams, 2001) as well as reading (e.g., Dijkstra & Van Heuven, 2002; Van Heuven, Dijkstra, & Grainger, 1998).

If one or more additional languages are activated in parallel, the issue then becomes one of cross-language selection in addition to selection of semantically similar within-language competitors. Cross language selection, recently referred to as the “hard problem” (Finkbeiner, Gollan, & Caramazza, 2006), is complicated by the fact that while within-language competitors most often differ in at least some semantic aspect or feature, cross-language competitors regularly include synonyms that might be expected to receive activation equal to the target in balanced bilinguals (e.g., Jescheniak & Schriefers, 1998; Peterson & Savoy, 1998; Wheeldon & Monsell, 1992). A potential solution to this problem has been proposed by Grosjean (1997; 1998; 2001) in the form of a “language mode” that adjusts the relative activation of a bilingual’s languages depending on external cues. Cues include the languages of the interlocutor (e.g., whether he or she shares the same languages as the speaker), proficiency, attitudes about the languages and language mixing, and the task to be completed. According to Grosjean (1998), a bilingual can shift between bilingual and monolingual modes depending on the situation and external cues. For example, a Korean-English bilingual speaking to someone with no knowledge of English would shift into (or toward) monolingual mode (i.e., Korean only), which then adjusts the activation of lexical items to make Korean more accessible. In the case of a bilingual speaking to another bilingual with the same languages and proficiency, the speaker would shift back to a more bilingual mode, which could result in the increased activation of one of the two languages depending on cues such as environment, topic, and interlocutor’s language preference.

While Grosjean's (1997, 1998, 2001) Language Mode framework does provide a clear model for bilingual lexical selection, the powerful influence of external cues on bilingual language processing is not supported by recent empirical findings. Dijkstra (2005) emphasizes that the existing literature now shows bilingual lexical access to be profoundly language non-selective, despite external cues and other top-down factors (see also Sandoval, Gollan, Ferreira, and Salmon, 2010). If bilinguals are not able to simply turn off one language in favor of another, and if both languages receive activation during processing, then the question becomes how bilingual lexical selection is achieved. Two competing groups of theories have been proposed to account for bilingual lexical selection: Language Specific Models (e.g., Costa, Miozzo, & Caramazza, 1999; Finkbeiner, Almeida, Janssen, & Caramazza, 2006; La Heij, 2005) and Competition-For-Selection Models (e.g., Green, 1998; Kroll, Bobb, Misra, & Guo, 2008; Kroll, Bobb, & Wodniecka, 2006). Generally, both types of models concede that lexical items in both languages receive at least some activation during bilingual language processing. Where they differ, however, is if non-target language items are available for selection and, if they are, the control mechanism responsible for ensuring selection of target items in the face of non-target competitors.

2.2.1 Language-Specific Lexical Selection

Selective language activation is most often associated with processing and production in a bilingual's native or dominant language (Bloem & La Heij, 2003; Kroll, Bobb, & Wodniecka, 2006). However, processing models claiming language-specific lexical selection for L2 also exist. The fundamental claim underlying language-specific

selection models is that while lexical items may receive activation at some point along the time course of language processing, only items in the target language are available for selection (e.g., Costa, 2005; Costa et al., 1999; La Heij, 2005). In language-specific models, the locus of selection and control reside within the lexicon of the target language, thereby avoiding the requirement for an external language control mechanism. Roelofs (1998) put forward an early language-specific model which stated that language access is conceptually driven, and that language production rules are constrained to the intended language. The result is therefore a language production process that is limited to only lexical items of the target language, regardless of activation levels of lexical items in the non-target language.

Evidence in support of language-specific lexical selection comes from a long line of studies examining bilingual processing of cognates, homographs, as well as other target words that vary with respect to number and degree of translation equivalents (e.g., Caramazza & Brones, 1979; De Groot, Delmaar, & Lupker, 2000; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Roelofs, 1998; Soares & Grosjean, 1984). As cognates are identical (or nearly identical) in orthographic form and share meaning across languages, bilingual processing of cognates provides insight into potential interaction between two language systems. Homographs, words that share orthographic form but not meaning, have also been used to investigate whether target language processing is affected by non-target language lexical items. The key question for studies examining lexical access and selection is whether words that occur in both languages, such as cognates and homographs, are processed differently than words that only occur in one language. If differences exist, in reaction times or accuracy, for example, it would

suggest an interaction between the languages, and therefore provide evidence against language-select models. No differences in reaction time or accuracy would therefore provide support for processing models positing language-specific lexical selection. A series of studies spanning more than 20 years (e.g., Caramazza & Brones, 1979; De Groot, Delmaar, & Lupker, 2000; Dijkstra; Soares & Grosjean, 1984) has demonstrated a fairly consistent pattern of results, with no significant reaction time differences observed between critical test items and control words.

In further support of the language-specific model, Costa and colleagues (1999) cite the results of a series of picture-word interference experiments involving highly-proficient Catalan-Spanish bilinguals. Over the course of seven picture naming tasks, participants named pictures in Catalan while also being shown a variety of distractor words. The distractor stimuli were manipulated to include both Spanish and Catalan words, words in both languages that were related semantically and phonologically to the target picture, and words that were related to the translation equivalents of the target pictures (at varying SOAs). Data from the experiments revealed facilitation from identical distractors within each language, although results did vary with certain language pairs and at different SOAs. Semantically-related distractors produced interference in both languages, and the degree of interference did not differ between Spanish and Catalan. Phonologically similar distractors facilitated picture naming, although, critically, facilitation effects were not observed for translation equivalents (i.e., Spanish distractors that translate into phonologically similar Catalan words did not facilitate picture naming). According to Costa and colleagues, these results suggest a model of lexical access that includes the following assumptions: “(a) the semantic system sends activation in parallel

and to equal extents to the lexical entries in the two lexicons of a bilingual; (b) *only* the lexical nodes in the lexicon which is programmed for response are considered for selection; and (c) there are *nonlexical* mechanisms that allow a written word to activate its phonological segments” (Costa, 1999; p. 387). According to this account, cross-language interactions are possible, but there is no competition for selection between lexical items of two different languages. These findings reinforce the central claim of language-specific models that competition for selection of lexical items occurs within, but not across, languages.

2.2.2 Competition-for-Selection

In contrast to language-specific models of lexical selection, competition-for-selection models (e.g., Green, 1998; Kroll, Bobb, & Wodniecka, 2006; Kroll, Bobb, Misra, & Guo, 2008) include lexical items of both languages as potential candidates for selection, and rely on a control device outside of the lexicon to ensure selection of the target language lexical item. Green (1998) proposed an influential model of lexical selection termed the Inhibitory Control Model. Two critical elements of the model include an overarching language schema that serves to provide a degree of top-down control, and a mechanism that reactively inhibits non-target language lexical competitors. Regarding the top-down influence on processing and lexical selection, a language cue weights lexical candidates in the target language at the expense of non-target language competitors. Critically, Green’s (1998) model stresses that the language cue is, by itself, unable to completely suppress cross-language selection candidates. A cognitive control

mechanism outside of the lexicon is required to further ensure selection of the proper lexical item through reactive inhibition of non-target competitors.

According to the Inhibitory Control Model, lexical items in both languages receive activation from higher level conceptual activation, but non-target language items are then reactively suppressed. Target and non-target language items are marked by language tags, a concept also adopted by several other bilingual language production models (e.g., La Heij, 2005; Poulisse & Bongaerts, 1994). A key aspect of this reactive suppression is that the amount of inhibition is proportional to the amount of activation. Therefore, non-target items that receive the highest amount of activation are also subjected to the highest levels of inhibition. Behavioral evidence from psycholinguistic studies supports this claim. In a seminal study, Meuter and Allport (1999) demonstrated that bilinguals performing a number naming language switch task took longer to switch from their second language to their dominant language. Although this may initially seem counterintuitive, it is exactly what Green's (1998) Inhibitory Control Model predicts. Because the first language was the dominant language for the participants in Meuter and Allport's (1999) study, the first language would require a higher degree of inhibition during number naming in the participants' second language. In order to switch back to their first language in the switch condition, the participants had to first overcome the higher degree of inhibition to access the first language lexicon, resulting in a larger switch cost from the second language to the first. It should be noted, however, that the language switch data are not entirely consistent across polyglots with different numbers of languages and varying degrees of proficiency. In Costa and Santesteban (2004), highly proficient multilingual subjects demonstrated no differences while switching between

their first and a less proficient third language, which led the authors to suggest that the language experience of balanced bilinguals led to qualitatively different processing compared with less proficient language learners. Further clouding the issue, Costa et al. (2006) did find switch costs for subjects switching between their third and fourth languages.

Kroll et al. (2006) add some clarity to the issue by positing that myriad variables beyond just proficiency and age of acquisition affect lexical selection and, consequently, data from studies relying on tasks such as picture naming interference and language switching. It is important to note that Kroll et al. (2006) concede that language selectivity may sometimes be observed, as in the case of L1 processing occurring too quickly to receive interference from a weak L2 (see Bloem & La Heij, 2003). However, language selectivity only occurs in somewhat exceptional circumstances, and selection-for-competition is the default processing mode for bilinguals. Regarding inconsistent results from studies such as Costa et al. (2006), Kroll and colleagues claim that language selection can occur at more than one level (i.e., lexical and phonological, in some cases) and that factors such as proficiency and experience of the bilingual, demands of the processing task, cognitive resources available, and the degree of activity of the non-target language all influence the actual locus of selection. Further research specifically targeting these variables is needed.

2.2.3. BIA and BIA+ Models

Whereas Green's (1998) Inhibitory Control model is viewed as a representational model for bilingual language production, the Bilingual Interactive Activation model (BIA model, Dijkstra & Van Heuven, 1998; Van Heuven, Dijkstra, & Granger, 1998) and the BIA+ model (Dijkstra & Van Heuven, 2002) focus specifically on bilingual visual word recognition. The original BIA model is based on a language non-select framework that posits four levels of linguistic representations: letter features, letters, words, and language tags. Unlike production-driven, top-down activation starting at the concept level (e.g., language production in the Inhibitory Control model), activation moves bottom-up in the BIA model. Upon reading a word, for example, individual features of letters receive activation first, and then each feature activates the letters that form the word. The letters then activate the words that contain the specified letters (and letter combinations), with activation continuing upward to language tags, which represent every language for which a word was activated (e.g., both English and Spanish language tags would be activated for the letter string "PIANO"). While the process is generally considered bottom-up, activation is also sent back down after the language nodes are activated. This is in addition to cross-language activation and inhibition required to eventually select the appropriate lexical candidate for the presented word. Context does play a role in the process through the relative activation of language nodes, and the resting activation level of words is determined by factors such as frequency and learner proficiency (Dijkstra, 2005; Dijkstra & Van Heuven, 1998).

While the BIA model provided a basic framework for bilingual visual word recognition, it was limited to orthographic representations and did not account for phonological and semantic influences. Assuming a single, integrated lexicon, the BIA+

model (Dijkstra & Van Heuven, 2002) expands on the basic BIA model (i.e., including orthographic, phonological, and semantic representations), and provides a more detailed account of the mechanisms through which context affects lexical selection. The BIA+ model differs from the initial BIA model in that it does not allow for direct non-linguistic context effects on the word recognition process. While semantic and syntactic aspects of the sentence context can directly influence the activation state of word candidates, non-linguistic context effects can do so only indirectly. In summary, the BIA+ model presents a language non-select framework for bilingual visual word recognition that has evolved from the initial BIA model to include orthographic, phonological, and semantic representations, as well as specific mechanisms for accounting for (and limiting) linguistic and non-linguistic context effects.

Whereas Green's Inhibitory Control theory (1986; 1998) continues to play a central role in studies examining switch and mix effects in bilingual language production tasks, models focused more specifically on bottom-up processing, such as the BIA+ model (Dijkstra & Van Heuven, 2002) are potentially more useful in examining processes underlying language switching in receptive tasks. As the focus of this study includes production tasks and receptive tasks, both models will be referred to in an attempt to clarify mix and switch effects, as well as their underlying cognitive processes.

3 Bilingual Language Mix and Switch Effects

3.1 Language Switch Paradigm

One research method utilized to investigate lexical selection involves language switching, which in several studies (e.g., Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Meuter & Allport, 1999, Schwieter & Sunderman, 2008) has provided evidence supporting the role of inhibitory control in bilingual language processing (e.g., Green, 1998). Language switch experiments are based on the task switching paradigm, in which participants are trained on two or more simple tasks and are then required to execute one of the tasks based on a given cue (e.g., Rogers & Monsell, 1995; Monsell, 2003). This allows for two types of responses: one in which the task is the same as the previous task, and one in which the participant is required to switch to the alternate task. Data from task switches include switch costs, with responses on switch trials generally taking longer than non-switch trials, and mix costs, which is the more general processing cost associated with doing two or more different tasks within the same block.

Interestingly, a series of studies have demonstrated that switches from a difficult task to an easier task result in larger switch costs than switches from an easier task into a more difficult task (e.g., Allport, Styles & Hsieh, 1994; Allport & Wylie, 2000; Rubinstein, Meyer & Evans, 2001, Yeung & Monsell, 2003). In addition to mix and switch costs, Monsell (2003) also lists preparation effects and residual costs as phenomena of interest. Preparation effects refer to the fact that average switch costs are usually reduced when participants have advanced knowledge of the upcoming task and have time to prepare. Preparation generally does not eliminate switch costs entirely, however, and the remaining processing costs are referred to as residual costs (Monsell, 2003). Together,

these concepts provide insight into processes and costs associated with performing two or more, often competing, tasks. Recently, this research paradigm has been used extensively to investigate bilingual language processing, where analyses of switch and mix costs provide clues as to how bilingual language selection occurs (e.g., Costa & Santesteban, 2004; Costa, Santesteban, & Ivanaova, 2006; Kroll & Stewart, 1994; Levy et al., 2007; Meuter, 2005; Meuter & Allport, 1999).

3.2 Switch Effects in Bilingual Language Processing

In a seminal study, Meuter and Allport (1999) utilized the task switch research paradigm to investigate bilingual language switching and lexical selection. In this study, bilinguals were tasked with naming numbers in either their first or second language, with the language switches occurring in an unpredictable pattern. Reaction times were analyzed and, as expected, there was generally an increased cost on switch trials compared with non-switch trials. When the direction of switching was analyzed, an interesting pattern emerged; the switch cost was larger switching from the less proficient second language to the dominant first language. This finding is in line with predictions made by Green's (1998) Inhibitory Control model. Specifically, Green's model states that the dominant language requires greater inhibition (or suppression) to allow for the selection of the weaker L2. According to Meuter and Allport (1999), increased inhibition of L1 occurs when digits are named in the L2. When switching back to the L1 from the L2, the persisting inhibition from the previous trial has to be overcome, leading to a reaction time cost and longer response latency.

Jackson, Swainson, Cunnington, and Jackson (2001) report behavioral and ERP findings that support the role of active inhibition of the first language during L2 processing. Replicating Meuter and Allport's (1999) critical finding, behavioral data from a switch task demonstrated higher switch costs from L2 to L1. In addition, ERP results suggested that L1 receives more inhibition when switching to L2 than the second language receives when switching to L1. The central finding of increased L1 inhibition during L2 processing provides support for the language non-select lexical framework, as well as the role of inhibitory control in bilingual language processing.

Meuter and Allport (1999) and Jackson et al. (2001) provided early support for Green's (1999) Inhibitory Control model based on asymmetric switch costs for non-balanced bilinguals. Costa and Santesteban (2004) replicated the asymmetric switch cost findings for non-balanced bilinguals through a series of picture naming switch tasks, and extended the findings by examining the performance of balanced bilinguals. Picture naming performance by Korean (L1) second language learners of Spanish and highly proficient Spanish-Catalan bilinguals was compared in a series of five experiments. The first experiment revealed a switch-cost asymmetry, with switches into the L1 (Korean) taking longer than switches into the L2 for the low-proficiency Spanish learners. However, in a follow-up experiment, this switch cost asymmetry was not present for highly proficient Spanish-Catalan bilinguals in either of their dominant languages or a much weaker L3 (English). Also, results showed that these individuals named pictures significantly faster in their less dominant language. With the final experiment confirming that the faster naming latencies in the less dominant language was not a result of lexicalization bias, Costa and Santesteban concluded that the switching performance of

highly proficient bilinguals does not rely on the same mechanisms underlying switching for low proficiency bilinguals. Based on the overall results from the study, the claim is made that whereas inhibition is necessary for language control for lower-proficiency bilinguals, experienced highly-proficient and balanced bilinguals (i.e., early bilinguals) rely instead on attentional control that enables more top-down control of processing. This is a bold claim on two levels. First, this suggests that lexical selection in beginning and low-proficiency L2 learners evolves from a language non-select framework, which relies on inhibition, into controlled processing that, in effect, is to a large extent language specific. This developmental shift is also interesting from the point of view of aptitude as commonly defined in the field of Second Language Acquisition. As introduced in Chapter 1, SLA aptitude is most commonly thought to be more or less fixed, and at least not greatly influenced by language learning experience and use. Therefore the qualitative shift in processing advanced by Costa & Santesteban (2004) is of potentially great importance to the study of SLA aptitude.

In a later study, Costa, Santesteban, and Ivanova (2006) modified Costa and Santesteban's (2004) language control theory slightly based on a series of four experiments examining the picture naming performance of highly proficient bilinguals. Costa et al. (2006) attempted to replicate the symmetrical switch cost findings for highly proficient bilinguals, and also investigated the role of age of L2 acquisition, degree of language similarity, and the relative switch costs for multiple languages of varying proficiency (L2, L3, and L4). Results from the study confirmed symmetrical switch costs for the highly proficient bilinguals for languages in which their proficiency was balanced, and asymmetric switch costs for language pairs that included a weaker language.

Critically, symmetrical switch costs for balanced language pairs were not affected by age of acquisition or similarity between language pairs. Costa et al. (2006) considered these results further support for the language control framework that includes a proficiency-driven shift from inhibitory control to top-down attentional control, with one modification. Costa and Santesteban (2004) suggested that age of acquisition for the second language was a critical factor in switch cost symmetry for balanced bilinguals. However, results from Costa et al. (2006) demonstrated no differences based on age of acquisition. Therefore, the language control framework put forward by Costa and Santesteban (2004) was modified slightly to remove the early age of acquisition requirement for balanced bilingualism and symmetric switch costs. Based on the bilingual picture naming results from Costa and Santesteban (2004) and Costa et al. (2006), Costa and colleagues also posited that lexical robustness, representing the strength of lexical connections, might play a role in the shift from inhibitory control to top-down, language select bilingual processing.

Recent neuroimaging studies have also employed the task switching paradigm to investigate bilingual language switching and the possible role of inhibitory control. Christoffels, Firk, & Schiller (2007) report results from a picture naming task in which Dutch-German unbalanced bilinguals named pictures in single-language blocks as well as a mixed language condition. Stimuli included cognates, which allowed Christoffels et al. (2007) to demonstrate non-target language activation related to cognates compared with control items, providing additional support for the language non-select framework of lexical selection. In the mixed language block, participants showed symmetrical switch costs despite being rated as unbalanced bilinguals. The lack of asymmetric switch costs

for unbalanced bilinguals is at odds with previous studies in this area (e.g., Costa & Santesteban, 2004; Costa, Santesteban, and Ivanova, 2006; Meuter & Allport, 1999). However, in terms of L1 and L2 items in the mixed condition, participants performed as expected with pictures being named slower in the L1 than the L2. Summarizing the results of this study, Cristoffels et al. (2007) propose that language select and language non-select processing might both be utilized during bilingual switch tasks, with language select control applied on a trial-by-trial basis with inhibition playing a role related to language context effects. Interestingly, Cristoffels et al. attribute global inhibition effects in the study to selective adjustments to the availability of only the L1, and not relative adjustments to the activation of L1 and L2.

The picture naming language switch studies reviewed to this point provide supporting evidence for the role of inhibition in general task switching (see Koch, Gade, Schuch, & Philipp, 2010, for review) as well as bilingual language switching, at least in the case of low proficiency learners. Two recent studies, however, have challenged this conclusion. Finkbeiner, Almeida, Janssen, and Caramazza (2006) challenged the original interpretation of Meuter and Allport's (1999) results based on what they viewed as a confound in the design of the study. The central point of disagreement is Finkbeiner et al.'s claim that asymmetric switch costs are due to bivalent stimuli being paired with two distinct response types. Whereas univalent stimuli most often do not lead to switch cost asymmetry, switch costs are confounded in Meuter and Allport (1999) due to the same digits being named in both the L1 and L2. Finkbeiner et al (2006) tested this idea by running a digit naming experiment similar to Meuter and Allport (1999), while also adding a picture naming component in which the pictures were only named in the

participant's L1 (thereby removing the valence-related two language confound). Results from the study demonstrated, as predicted, that asymmetric switch costs were present for the bivalent digit naming stimuli. Also, as predicted, the single-language picture naming data revealed no switch cost asymmetry. The lack of asymmetric switch costs was replicated when the picture naming task was replaced with a dot counting task. When only counting the number of dots in the participants' L1, asymmetric switch costs were not observed. Upon further investigation, Finkbeiner et al. (2006) claimed that results from their study demonstrate that the factor underlying switch cost asymmetry is not inhibition or suppression, as claimed by Meuter and Allport (1999), but rather is tied to the notion of valence and speed of response availability.

A second challenge to laboratory-based language switching studies is raised by Gollan and Ferreria (2009), and focuses on the common practice of mandating the response language during bilingual naming tasks. Gollan and Ferreria (2009) posited that asymmetric switch costs resulted, at least in part, from the participants' inability to choose the response language. Whereas, in a natural conversational setting, bilinguals are often free to choose between L1 and L2 lexical items when speaking to a bilingual with a similar language skill set, laboratory-type picture naming experiments force bilinguals into lexical selection that may not be their first choice in natural settings. Several interesting results were reported. First, L1 dominant bilinguals who typically showed asymmetric switch costs demonstrated switch cost symmetry when they were allowed to switch languages freely (i.e., choose their response language). These results suggest that the switch cost asymmetry reported in earlier studies may be the result of, or at least strongly influenced by, the requirement to respond in a specific language as opposed to

the language of the participants' choosing. Second, while a different pattern of switch costs was observed when participants freely chose their response language, overall results demonstrated an inhibitory effect on the dominant language. This is in line with findings from earlier studies such as Meuter and Allport (1999), and suggests that inhibition does in fact play a role in situations mixed language environments. Finally, as noted by Kroll, Bobb, Misra, and Guo (2008), the pattern of switch costs reported by Gollan and Ferreira (2009) demonstrates that valence, as put forward by Finkbeiner et al. (2006), is not the critical factor in determining the pattern of switch costs.

The challenges presented by Finkbeiner et al. (2006) and Gollan and Ferreira (2009) demonstrate the complexity of bilingual task switching research. In addition to the important methodological considerations raised by these studies, the accurate estimation of bilingual language proficiency is also critical to bilingual language switching research and language control theories such as those proposed by Costa and colleagues (e.g., Costa, 2005; Costa, Santesteban, & Ivanova, 2006). A recent bilingual language switching study by Schwieter and Sunderman (2008) focused attention on the need for a reliable measure of proficiency while investigating the proposed proficiency-driven shift from inhibitory control to language-specific processing. This study is notable for several reasons. First, the researchers utilized a verbal fluency measure (adapted from Gollan, Montoya, and Werner, 2006) to measure what Schwieter and Sunderman refer to as "the robustness of the lexicon" (2008: p 223). In this task, the participants were verbally given a semantic category, and were then asked to name as many members of the category as possible. There were a total of ten categories and all of the correct responses were added together to provide a final score, which was then used in analyses of language switch performance.

By combining the results of this proficiency measure with participant performance on the language switch task, Schweiter and Sunderman (2008) not only provided evidence that a proficiency-based shift from inhibitory control to language-specific processing exists, but also provided an estimate of lexical robustness required to engage the mechanism. The results from this study are potentially very important to the study of bilingual language switching because they highlight the importance of accurately estimating second language proficiency and what elements of proficiency might be directly related to changes in processes underlying bilingual language switching.

3.3 Mix Effects and the Potential Influence of Repetition

In addition to switch costs, mix effects have been observed in bilingual switching tasks in which more than one response language is required during a single block. When naming pictures using only the dominant first language (L1), bilinguals demonstrate a reaction time advantage compared to single language L2 picture naming (e.g., Christoffels et al., 2006; Kroll, Michael, Tokowicz, and Dufour, 2002). However, a shift occurs in blocks that require responses in both languages (i.e., mixed condition); first language responses are often slower than L2 responses (e.g., Phillip, Gade, & Koch, 2007). Specifically, an L2 processing advantage appears to arise in conjunction with an apparent L1 disadvantage in mixed picture naming conditions. While the source of these effects has yet to be concretely identified, one possible contributor may be uneven repetition effects for first and second language stimuli in tasks such as bilingual picture naming.

Effects of repetition, often resulting in enhanced processing for repeated items, are well established in the literature (e.g., Bajo & Canas, 1989; Ferrand, Humphreys, & Segui, 1998; Ostergaard, 1998; Rayner & Duffy, 1986; Wheeldon & Monsell, 1992). Critical to understanding mix and switch studies results, comparisons of repetition priming effects in bilingual language tasks have demonstrated larger repetition effects for the weaker language (e.g., Alvarez, Holcomb, & Grainger, 2003; Hernandez, Bates, and Avila, 1996). This L2 advantage has been observed even when the corpus frequency was matched across languages (Duyck, Vanderelst, Desmet, & Hartsuiker, 2008). Several explanations have been put forward for this phenomenon. For example, Ostergaard (1998) posited that the relative ease of the task modulates the magnitude of repetition effects, and Kroll and de Groot (1997) attribute greater L2 repetition priming effects to weaker conceptual and lexical level links benefiting more from repetition than stronger, more well-established first language links. Yet another account attempts to explain priming asymmetry, particularly cross-language priming effects, by positing an episodic memory-based model for lexical development (Jiang & Forster, 2001).

Recent studies have also focused on the interaction of word frequency and repetition, with several studies finding greater frequency effects in L2 compared with L1 (e.g., Ivanova & Costa, 2008; Gollan et al., 2008). Some researchers have attributed differences in L1 and L2 performance to relative experience with each language. For example, Gollan, Montoya, Fennema-Notestine, & Morris (2005) state that, in effect, being bilingual is analogous to having a lexicon of lower-frequency words compared to that of monolinguals. Critical to the examination of potential effects of repetition on mix and switch effects, Gollan et al. (2005) found that bilinguals demonstrated a greater

benefit from repetition compared to monolinguals. Specifically, they found that despite bilingual picture naming being generally slower than picture naming by monolinguals, reaction time differences disappeared after four presentations. That is, repetition effects led to a speed up in reaction time that erased the initial bilingual disadvantage in reaction time. Summarizing recent behavioral and ERP data, Runnqvist, Strijkers, Sadat, & Costa (2011) provide further evidence for a frequency-centered account of bilingual disadvantage relative to monolinguals, as well as the potential differential influence of repetition.

While explanations regarding the origin of the effects vary, differential L1 and L2 repetition effects have been clearly demonstrated. Therefore, depending on the design of tasks such as a bilingual picture naming task, unequal repetition effects might contribute to a processing advantage for L2 stimuli in a mixed block condition. The differential effect of repetition on first and second language processing will be discussed in greater detail throughout this study.

Overall, the literature on bilingual language switch and mix effects is both complicated and heavily debated. However, the studies reviewed here show that progress is being made toward understanding the processes underlying language switching and mixing, the effects of critical learner variables such as proficiency, and potential proficiency-driven shifts in lexical access and selection. This study aims to further clarify switch and mix-related effects on bilingual language processing.

Up to this point, the main study foci of second language processing, mix, and switch costs have been reviewed. The next section discusses potential implications of this research on Second Language Acquisition theory and measurement of second language

acquisition aptitude. First, the basic elements of SLA aptitude will be introduced. Then, cognitive and inhibitory control will be discussed in more detail. Finally, the conceptual link between inhibitory control, mix and switch costs in bilingual language processing, and second language aptitude will be discussed. This will be followed by an overview of the current study, research questions, and a detailed presentation of study methodology.

4 Cognitive Control as Second Language Acquisition Aptitude

4.1 Second Language Acquisition Aptitude

While related fields such as Educational Psychology traditionally take a broader view of aptitude as all characteristics that an individual brings to a learning situation (e.g., Cronbach, 2002; Cronbach & Snow, 1977), current, mainstream SLA has adopted a stricter, narrower view of aptitude that is usually limited to cognitive components. The concept of aptitude, as employed in SLA, is often limited to cognitive aptitude, and is considered generally stable and largely the result of genetics and early experience (DeKeyser & Koeth, 2010; but see Dörnyei, 2009, for a broader view of SLA aptitude). Critically, according to the narrow view, SLA aptitude is not significantly affected by previous second language learning experience or use (Carroll & Sapon, 1957). Herein lies the contradiction. On one hand, language control theories have recently been proposed based on mechanisms that change over time as a direct result of learning and experience. On the other hand, the field of SLA maintains a more conservative definition that generally rejects the fundamental concept that aptitude changes significantly over time due to language learning experience and language use. This is far from simply a theoretical debate, as the issue has real, high-stakes implications for a wide variety of language learners. One example is the large number of US government foreign language professionals whose scores on aptitude tests taken early in their careers, such as the Defense Language Aptitude Battery (Petersen & Al-Haik, 1976) and Modern Language Aptitude Test (Carroll & Sapon, 1959), can define their “language learning aptitude” throughout their careers. Regardless of language learning experience, success using foreign language(s) on the job, and any strategies or cognitive benefits gained from years

of second language use, the opportunity to cross-train into a more difficult language might be denied based on the results of an aptitude test taken years before (even before the individual had any significant experience with learning a second language). This potentially career-limiting practice is tied closely to the view of aptitude espoused by the field of Second Language Acquisition; Second language learning aptitude is generally stable and not significantly influenced by language learning experience or even years of using a second language on the job. However, with an increasingly large body of research demonstrating significant bilingual advantages across a wide range of general cognitive control abilities (e.g., Bialystok, 2007; Bialystok et al., 2005; Bialystok, Craik, & Ryan, 2006; Hernandez, Costa, Fuentes, Vivas, & Sebastian-Galles, 2010), and separate lexical selection and access studies suggesting that control over a second language improves with increased experience and proficiency (e.g., Costa, 2004; Costa et al., 2006; Schwieter & Sunderman, 2008), an evaluation of the degree to which SLA aptitude is actually shaped by experience appears justified. At the very least, more empirical research is needed to examine language control theories that posit a direct relationship between increased proficiency and qualitative changes in how second and third languages are processed. One potential starting point is closer examination of individual differences in cognitive control, specifically inhibitory control, and how they might relate to second language processing advantages.

4.2 Inhibitory Control

Inhibitory control lies at the heart of competition-for-selection models of language processing. In order to fully understand the potential role of inhibitory control in bilingual language processing, it is important to define the term as well as specify how it links to closely related concepts such as cognitive control, attentional control, and executive control. Cognitive control has been described as a collection of processes within the human cognitive system that allow for the performance of specific tasks through adjustments in perceptual selection, response biasing, and the on-line maintenance of contextual information (Botvinick et al., 1999). Inhibitory Control, more specifically, can be described as the ability to inhibit responses to irrelevant stimuli during processing of a cognitively represented goal (Rothbart & Posner, 1985). In this sense, inhibitory control (e.g., Green, 1986; 1998), attentional control (e.g., Cowan et al., 2005; Kane et al., 2001; Segalowitz & Frenkiel-Fishman, 2005), and executive control (e.g., Baddeley & Hitch, 1974; Baddeley, 1986; Colzato et al., 2008) can be organized under the more general umbrella term of cognitive control.

Evidence for overlap between inhibitory control and general cognitive control has been presented in recent studies. Abutalebi & Green (2007) build on Green's (1998) Inhibitory Control Model and claim that the control required for lexical selection in bilinguals is not independent of the control required for "staying on task" and language switching. Abutalebi & Green (2007) also imply a correspondence between mechanisms of language control and the selection of language non-specific actions in the face of competing cues. Wang, Xue, Chen, Xue, and Dong (2007) investigated the neural bases of asymmetric language switching in second language learners and, utilizing fMRI, found activation for both general executive regions and task-related regions, but no evidence for

a specific region dedicated to language switching (see also Hernandez, Dapretto, Mazziotta and Bookheimer, 2001; Hernandez, Martinez and Kohnert, 2000). Based on this view, there appears to be strong overlap between a general view of cognitive control and the cognitive and inhibitory control closely tied to requirements for communicating in a second language.

4.3 Individual Differences in Cognitive Control

Individual differences in cognitive control and inhibitory control have been demonstrated in the literature. Developmental differences between children and adults result in children being more susceptible to interference and less able to inhibit non-appropriate responses than adults (Bunge et al., 2002) and the experience of early bilinguals in controlling attention to two languages has been shown to boost the development of executive control processes (Costa, Hernández, Costa-Faidella, Sebastián-Gallés, 2009; Bialystok, 1999, 2007; Kovacs & Mehler, 2009; Martin-Rhee & Bialystok, 2008; Prior and MacWhinney, 2010). Recent developments in the literature on bilingual language processing have implicated inhibition as a key cognitive mechanism supporting bilingual language use (e.g., Abutalebi, 2008; Hernández & Meschyan, 2006; Kroll, Bobb, Misra, & Guo, 2008), and a series of studies have found that highly proficient bilinguals outperform their monolingual counterparts on the antisaccade task (Bialystok, Craik, & Ryan, 2006) and the Simon task (Bialystok et al., 2004), as well as other tasks requiring inhibitory control (Colzato et al., 2008; Costa, Hernández, & Sebastián-Gallés, 2008). Festman, Rodriguez-Fornells, and Münte (2010) administered a series of cognitive control tasks to bilingual participants and concluded that bilinguals

with stronger language control demonstrate a cognitive advantage in tests involving executive functions, and that the source of the advantage is general executive abilities. Taken together, these results suggest the possibility that individuals who demonstrate better inhibitory control skills may be cognitively better equipped to meet the demands of bilingual language processing, which makes this an issue of potentially great importance to both Psycholinguistics and Second Language Acquisition research. More specifically, effects of variation in inhibitory control skills may play a significant role in second language processing as measured by picture naming performance and therefore merit closer investigation. That is not to say that a direct, one-to-one relationship is expected between cognitive control and language control, however. Second Language Acquisition research has repeatedly demonstrated second language learning aptitude to be complex, multi-faceted, and often far from straight forward (see Robinson, 2001). However, the SLA and Cognitive Psychology literature point to a possible relationship between non-linguistic task switching ability and language control, and identifying this link between the two would further the understanding of second language learning aptitude. For these reasons, the potential relationship between general cognitive control and bilingual language switching is included in this study.

The relationship between individual differences in cognitive control and bilingual language switch performance was one focus of a recent pilot study examining mix and switch costs in second language processing. Results from the pilot study, in combination with the literature reviewed to this point, shaped the current study. The methods and results from the pilot study will be presented and discussed in the following chapter in

order to provide background information and data from which expectations for the current study were developed.

5 Pilot Study

A recent unpublished pilot study was conducted to investigate the role of mix and switch costs in bilingual picture naming. The design of the pilot study matches the 5-block design utilized in Experiment 1 of the current study. Foci of the pilot study included mix and switch costs as well as repetition effects; therefore, results from the pilot study were informative when planning and developing expectations for the current study. An overview of the pilot study, methods, and results will be presented as they relate to the design and expectations of the current study.

5.1 Research Questions

The pilot study was designed to explore language mix and switch effects reported in bilingual picture naming studies such as Costa and Santesteban (2004). Specifically, the study compared picture naming reaction times between single-language blocks of pictures with a mixed block condition, explored potential differential effects of repetition between the L1 and L2, and examined switch costs during a mixed language block. The potential link between language switch performance and individual differences in cognitive control was also investigated. Participants were highly-proficient Korean L1, English L2 bilinguals.

Research questions and hypotheses for the pilot study were as follows:

RQ 1: In single-language blocks, do highly proficient Korean-English bilinguals name pictures faster in Korean or in English?

Hypothesis 1: When pictures are presented in single-language blocks, highly proficient Korean-English bilinguals will name pictures faster in their L1 (Korean) compared with their L2 (English).

RQ2: Do highly proficient Korean-English bilinguals name pictures faster in Korean or English when pictures are presented in a mixed block (i.e. Korean and English pictures mixed together)?

Hypothesis 2: Highly proficient Korean-English bilinguals will name pictures faster in English when pictures are presented in a mixed block.

RQ3: Do highly proficient bilinguals demonstrate symmetrical switch costs as reported in Costa & Santesteban (2004)?

Hypothesis 3: The highly proficient Korean-English bilinguals will demonstrate symmetrical switch costs and replicate findings from Costa and Santesteban (2004).

RQ4: Is there a differential effect of repetition between L1 and L2 picture naming reaction times across blocks?

Hypothesis 4: Repetition effects for English stimuli will be larger than repetition effects for Korean stimuli.

RQ5: Does picture naming task switching performance correlate with performance in non-linguistic high/low and odd/even switch tasks?

Hypothesis 5: Switch costs from the picture naming tasks (English to Korean and Korean to English) will correlate significantly with performance on non-linguistic task switching tasks.

RQ6: Does picture naming performance correlate with individual differences in attentional control (Antisaccade task)?

Hypothesis 6: There will be a significant correlation between picture naming switch scores and Antisaccade percentage correct scores.

5.2 Participants

A total of 40 native speakers of Korean (22 Female, 18 Male, $M_{age} = 31.79$, $SD = 3.83$) who are highly proficient in English were recruited for the pilot study. Participants were recruited from the University of Maryland campus community by printed advertisements (flyers posted on campus) as well as electronic postings on the University of Maryland Korean Graduate Student Association website. The participants included 4

faculty members/ post-doctoral researchers, 29 PhD students, 6 MA students, and 1 undergraduate (the undergraduate came to the United States at age 16, had lived and studied in the United States for 6 years, and scored in the upper 10th percentile on the proficiency screening measure). The average length of stay in the United States at the time of testing was 3.9 years ($SD = 2.53$) and participants self-reported a daily language use ratio of approximately 40% English/ 60% Korean. Participants were paid a total of \$10 for participation in the 1 hour study.

5.3 Materials

Fifty four line drawing pictures of common objects were selected from the University of California, San Diego's International Picture Naming Project database (Szekely et al., 2004) and divided into two sets of 27 pictures, matched for length and English frequency based on the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993). One set of pictures was presented with a yellow background that indicated the pictures were to be named in Korean. The second set of 27 pictures was set on a blue background, which signified pictures to be named in English (lists were counterbalanced across participants). In addition to the two sets of critical items, one additional set of ten pictures was developed for a practice block in which participants were familiarized with the picture naming procedure as well as which color required a Korean response and which color required English.

In the practice block, participants were instructed that pictures with a yellow background were to be named in Korean. They then completed 5 trials in which pictures

with a yellow background appeared. Participants also completed one familiarization set of English only responses (blue background).

There were a total of 5 experimental blocks in addition to the initial practice block (as presented in Figures 1 and 1a). The experimental blocks were presented in the following order for the first condition (lists were counterbalanced so that the English block occurred first for half the participants);

1. All Korean (yellow)
2. All English (blue),
3. Korean and English Mixed,
4. All Korean repeated (repeat first Korean block)
5. All English repeated (repeat first English block)



Figure 1. Condition 1 block order



Figure 1a. Condition 2 block order

In the mixed language block, which allowed for measurement of switch and mix costs, pictures were ordered such that 1, 2, or 3 pictures of a single color occurred consecutively before a switch to the other language occurred. The original design called for using 40 pictures in AA BB AA BB format (Korean, Korean, English, English, Korean, Korean...), but this created the possibility that anticipatory effects might influence switch performance if participants figured out the presentation pattern. To mitigate this risk, 10 additional pictures (5 Korean, 5 English) were added to the study to allow for a more random-seeming presentation of pictures by interspersing 1 and 3-picture sets in with the original AA BB 2-picture set format. This accounted for 50 of the 54 stimuli items presented in the mixed block.

The remaining 4 picture stimuli were selected for inclusion as the first four pictures presented in the mixed block. The inclusion of these 4 pictures (2 Korean, 2 English) provided 4 pictures and 1 initial switch per list, which, while providing practice and a transition into the mixed block, were not scored. This was done to better ensure that the reaction times for the critical mixed block were not negatively affected by unintended consequences related to starting a new task such as unpreparedness or lack of attentional focus on the part of the participants. The same four practice pictures were also presented in the single-language blocks but were not scored.

Stimuli in the mixed block condition were counterbalanced across four lists such that each critical stimulus picture was named in Korean by half of the participants and English by the other half. The stimuli were further counterbalanced such that each stimulus picture occurred as a switch trial for half of the participants and as a non-switch

trial for the other half (with the exception of 2 pictures that occurred as switch trials across all 4 lists due to inherent ordering constraints).

Each of the 54 pictures was named a total of three times during the experiment. Each of the twenty-seven pictures in the Korean set was named once in the initial all-Korean block (random order), once in the mixed block (fixed order), and once in the repeated Korean block (random order). The English pictures were also named a total of 3 times during the experiment; once during both of the all-English blocks and once during the mixed trials. The experiment was designed in this way to enable analysis of potential differences in repetition effects between responses in Korean and English.

In addition to the main picture naming task, one nonlinguistic switching task (Miyake, Emerson, Padilla and Ahn, 2004) and one measure of inhibitory control, the Antisaccade task (Hallett, 1978; Hallett & Adams, 1980; Kane, Bleckley, Conway, & Engle, 2001) were administered in order to examine the potential relationship between inhibitory control ability and performance on the bilingual picture naming task.

5.4 Procedure

After providing informed consent, participants completed a Demographic Information and Language Use survey. This survey elicited information about participant language study history as well as current use of L1 (Korean), L2 (English), as well as any other languages known.

Participants were tested individually in a quiet room on a Dell desktop computer with 18" LCD monitor. The picture naming task was presented first using E-Prime 2.0 (PST, Pittsburgh, PA) and, in addition to reaction time data collected in E-Prime, voice

responses were recorded with Audacity voice capture software to allow for later error analysis. Participants wore a headset equipped with a built-in microphone, which was linked to the Audacity program, and spoke into an Audio-Technica AT20 microphone secured in a microphone stand and positioned in front of their mouth in a manner that was comfortable and did not obstruct the participants' view of the computer screen.

In a past pilot study utilizing a similar task, an ISI of 500ms separated the removal of the named picture and the appearance of the next picture stimulus. As this caused problems with extraneous noise causing the program to move to the next picture, the program was changed for this study so that the participant pressed the space bar to continue to the next stimulus picture. The target picture disappeared from the screen immediately after a voice response was detected and the prompt "Press space bar to continue" appeared on the screen (in English) until the participant pressed the space bar to advance to the next picture.

After completion of the picture naming task, participants completed the odd/even switch task second and anti-saccade measure as the final task.

Finally, participants completed a short exit interview. During this exit interview, participants were shown the 54 stimulus pictures used in the study (on the computer monitor) and were asked to name them in English and Korean. Pictures that could not be named correctly were noted in the participant's file and were not included in the analyses for that individual. Participants then had the opportunity to ask questions about the study, received compensation (\$10), and signed a receipt. They were thanked for their time and the experiment was concluded.

5.5 Data Analysis

High and low cut-off points for the reaction times were first set at 200ms and 3000ms. Responses with reaction times falling outside of this range were discarded. The participant mean and standard deviation were then computed and values +/- 3 SDs from the mean were also removed. Voice responses were then coded according to the following scoring system:

1. Correct
2. Liberal correct (e.g., “poodle” for the target “dog”)
3. Error (wrong response in correct language)
4. Language error (correct or incorrect response in wrong language)
5. Technical error (recording equipment problem)
6. Extraneous noise (e.g., lip smacking, “ummm...”)

Answers judged as “liberal correct” were treated as correct if all three responses (two single-language blocks and one mixed block) were the same. An example is the response “trousers” for the picture “pants.” Missing data resulting from technical errors (e.g., no voice capture despite a voiced response), extraneous noise, and incorrect responses were removed from analysis. Finally, any stimulus word missing from any of the three blocks (first single-language block, mixed block, or second single-language block) was removed completely for that participant. In sum, 13.5% of the data was removed during scoring and data cleaning. By participant, the amount of data removed

ranged from 2%-34%, and no participant was removed from the picture naming analysis due to poor performance.

Data preparation for the nonlinguistic task switching and antisaccade task included the removal of any reaction times above 3000ms and below 200ms. Reaction times above and below 3 standard deviations were also removed and the analyses for both tasks only included correct responses. No participants were dropped from the task switching analysis. One participant was dropped from the antisaccade analysis due to a mean reaction time of approximately 220 milliseconds for both the antisaccade and prosaccade critical blocks. During the experiment, the participant reported not being able to see any of the target stimuli and simply pressed the button continuously to move through the task as quickly as possible.

After preparation of the data, a repeated measures ANOVA was conducted to investigate differences between Korean and English reaction times within the mixed block as well as mean reaction times between single language and mixed language blocks.

In order to measure repetition effects, a 2 x 2 repeated measures ANOVA was conducted with 2 factors: Language (Korean and English) and Repetition (first or second single-language block presentation of stimuli picture). This analysis was conducted in order to reveal potential main effects of language and repetition as well as possible interaction effects (e.g., L2 benefiting more from repetition than L1).

Switch costs were examined by subtracting non-switch trial RTs from switch trial RTs within the mixed language block. A repeated measures ANOVA was used to

compare mean L1 to L2 switch costs with L2 to L1 switch costs to determine if asymmetry exists.

Potential effects of counterbalancing were examined with no significant differences in reaction times due to stimuli lists (e.g., “dog” presented with yellow or blue background) or presentation order (Korean or English block presented first). Finally, correlations were examined between individual difference measures and picture naming and task switching performance.

5.6 Results

The mean reaction times for correct picture naming responses are presented in Table 1.

Table 1. Pilot Test Picture Naming mean reaction times by block

1 st English Block	1 st Korean Block	Mixed Block English	Mixed Block Korean	2 nd English Block	2 nd Korean Block
1075.7 (177.6)	904.6 (150.4)	949.7 (135.6)	1035.5 (183.6)	779.2 (105.0)	798.0 (176.8)

The mean reaction time for correct responses in the first English block was 1075.7 ms ($SD = 177.6$) and the mean reaction time for the first Korean block was 904.6 ms ($SD = 150.4$). A repeated measures ANOVA showed this difference to be significant ($F(1, 39) = 35.62, p < .001$; $F(1, 49) = 47.16, p < .001$). Combining the first and second all-English blocks and comparing to the average of the first and second all Korean blocks also reveals a significant difference ($F(1, 79) = 13.40, p < .001$; $F(1,99) = 21.01, p < .001$) with faster reaction times for Korean responses ($M = 851.3, SD = 171.7$) than English ($M = 927.5, SD = 208.0$).

In contrast to the faster reaction times for Korean (L1) pictures in single-language blocks, the mean reaction time for correctly named Korean pictures ($M =$

1035.5, $SD = 183.6$) was slower than English pictures 949.7 ms ($SD = 135.6$) in the critical mixed block. Analysis of variance showed the difference to be significant ($F(1, 39) = 13.70, p < .05$; $F(1,49) = 20.53, p < .001$). In addition to the difference in mean naming latencies, the costs associated with mixing stimuli also differed by language. A significant difference exists between mix costs (Mean RT for first single-language block minus mixed block mean for that language) with Korean stimuli named 130.9 ms ($SD = 154.5$) slower in the mixed condition and English stimuli named 126.1 ms ($SD = 145.3$) faster in the mixed condition. This difference ($F(1,39) = 82.62, p < .001$; $F(1, 49) = 138.34, p < .001$) reveals a striking contrast with L1 picture naming negatively affected by the mixed condition (named more slowly) while L2 picture naming latency benefited from the mixed environment. To illustrate this point, mean reaction times by block are presented in Figure 2.

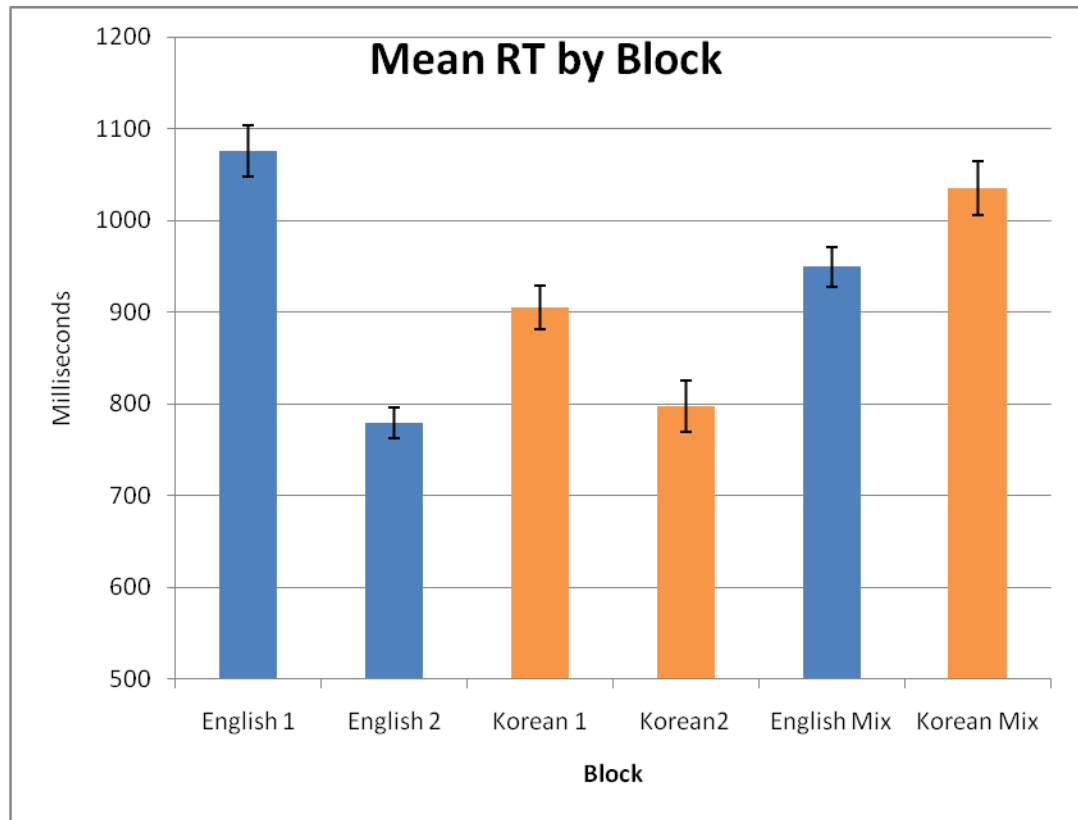


Figure 2. Pilot study Picture Naming Task mean reaction times by block

Examination of switch costs between Korean and English stimuli in the mixed condition revealed somewhat surprising results. Based on past literature demonstrating symmetrical switch costs for highly proficient bilinguals (e.g., Costa & Santesteban, 2004; 2006), similar results were expected with the Korean graduate students and faculty tested in this study. However, the mean switch cost for switching from Korean to English was 12.9 ms ($SD = 111.2$) and the average cost for switching from English to Korean was 109.54 ms ($SD = 175.4$). Naming latencies for switch and non-switch trials are presented in Figure 3. A 2 x 2 ANOVA with the factors “Language” (Korean and English) and “Type of Trial” (switch or non-switch) was conducted to examine the performance differences. The main effects of Language ($F(1, 39) = 12.20, p < .001$; $F(1, 43) =$

15.67, $p < .001$) and Type of Trial ($F(1, 39) = 13.74 = p < .05$; $F(1, 43) = 23.18, p < .001$) were significant, as was the interaction of language and trial type ($F(1, 39) = 10.04, p < .05$; $F(1, 43) = 6.42, p < .05$), with switches into Korean requiring more time.

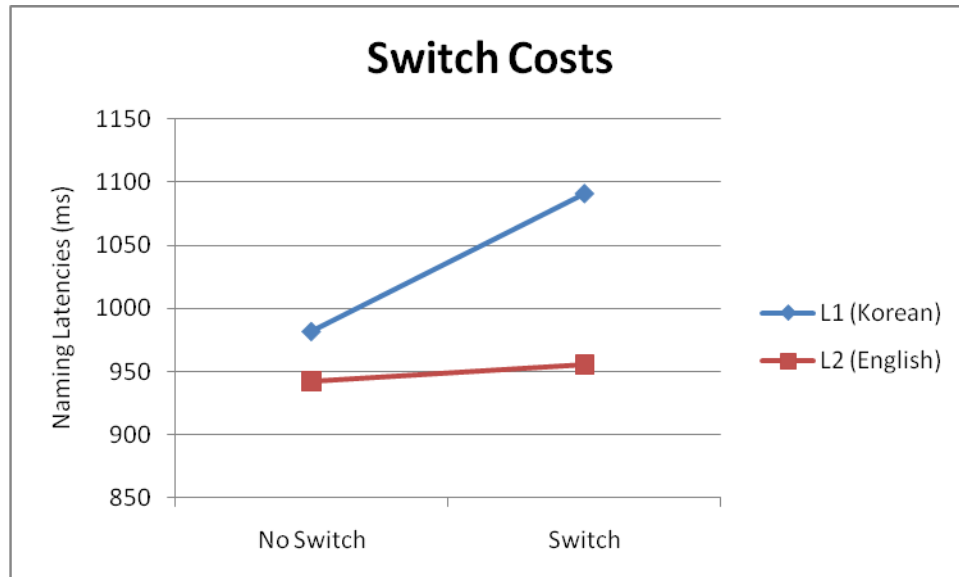


Figure 3. Pilot study Picture Naming Task switch data

A 2x2 (language x repetition) repeated measures ANOVA was conducted to examine repetition effects on mean reaction times between the first and second single-language blocks. The main effects of language ($F(1, 39) = 11.20, p < .05$; $F(1, 49) = 21.14, p < .001$) and repetition ($F(1, 39) = 178.57, p < .001$; $F(1, 49) = 223.16, p < .001$) were significant, as was the interaction of language and repetition ($F(1, 39) = 70.45, p < .05$; $F(1, 49) = 81.11, p < .001$), with pictures in the second all-English block named an average of 296.5 ms ($SD = 134.6$) faster than pictures presented in the first English block. Korean benefited to a lesser extent, with pictures in the second all Korean block named 106.6 ms ($SD = 101.6$) faster than the first.

Turning to the examination of individual differences in non-linguistic task switching and attentional control as measured by the Antisaccade Task, there were no significant relationships between these measures and picture naming performance. Examination of correlations between non-linguistic task switching, Antisaccade, and picture naming switch costs revealed significant correlations between only the odd/even and high/low components of the task switching task (.55, $p < .001$) and antisaccade and prosaccade components of the Antisaccade Task (.58, $p < .001$). The only other correlation to near significance at the $p < .05$ level was accuracy on the prosaccade component of the antisaccade task and switch costs from Korean to English (-.29, $p = .076$). Correlations between the individual differences measures and other dependent variables such as overall naming accuracy and mix costs were also examined. No significant correlations were found.

5.7 Discussion

The results will be discussed in relation to the six research questions and related hypotheses.

RQ 1: Do highly proficient Korean-English bilinguals name pictures faster in single-language blocks that require all Korean or all English responses?

Hypothesis 1: Highly proficient Korean-English bilinguals will name pictures faster in their L1 (Korean) compared with their L2 (English) when pictures are presented in single-language blocks.

Data from the study supported this hypothesis. When naming pictures in a single-language block, the Korean participants named pictures in their L1 an average of 171 ms faster than pictures named in an initial all English block. This naming

advantage held even when the average reaction times of both all Korean blocks ($M = 851$ ms) was compared with the average of the two all English blocks ($M = 927$ ms). As Korean was the first and most frequently used (as self-reported) language for the participants in this study, this finding was not surprising. However, it was important in that it set a baseline for the examination of potential costs when L1 and L2 stimuli were mixed in a single block. Specifically, it supported the assertion that the participants were still Korean dominant despite being highly proficient in English and immersed in an English-speaking environment. Therefore, the naming latency advantage for English in the mixed block, as discussed in RQ2, could not be attributed solely to language proficiency and was instead the result of naming in a mixed language environment. Comparing this result to earlier studies, it also suggested that the L2 naming advantage reported in Costa & Santesteban (2004) was a result of the mixed condition in which the stimuli were presented.

RQ2: Do highly proficient Korean-English bilinguals name pictures faster in Korean or English when pictures are presented in a mixed block (i.e. Korean and English pictures mixed together)?

Hypothesis 2: Highly proficient Korean-English bilinguals will name pictures faster in English when pictures are presented in a mixed block.

This hypothesis was supported by the data. In contrast to the faster reaction times for Korean (L1) pictures in single-language blocks, the mean reaction time for correctly named Korean pictures ($M = 1035.5$ ms) was significantly slower than English pictures ($M = 949.7$ ms) in the critical mixed block. Furthermore a robust

difference emerged between Korean and English mix costs with Korean stimuli named 130.9 ms ($SD = 154.5$) slower in the mixed condition and English stimuli named 126.1 ms ($SD = 145.3$) faster. This finding replicated results from Costa & Santesteban (2004), where a latency advantage for L2 over the participants' first language was observed. Interestingly, Costa and Santesteban stated that this effect would constitute support for larger inhibition for L1 lexical items if it were not for the fact that this would also require asymmetrical switch costs in this condition. As no asymmetrical switch costs were found for the balanced bilinguals in their 2004 study, an alternate explanation, the "language-specific threshold hypothesis" (p. 507), was postulated to reconcile the findings. However, results that include faster naming latencies for the L2 and asymmetrical switch costs would obviate the need for a more complicated, overly powerful explanation given that a more general inhibitory control-based account (Green, 1998) is sufficient to explain the reported effects. This is precisely what the naming latency and switch performance data from the study support.

It should be noted that performance in the mixed block was potentially affected by at least three variables: an effect of mixing Korean and English stimuli, repetition effects from stimuli in this block being presented for the second time, and the potential influence of language switches.

RQ3: Do highly proficient bilinguals demonstrate symmetrical switch costs as reported in Costa & Santesteban (2004)?

Hypothesis 3: The highly proficient Korean-English bilinguals will demonstrate symmetrical switch costs and replicate findings from Costa and Santesteban (2004).

Data from this study contradicted this hypothesis. Costa and Santesteban's (2004) finding of symmetrical switch costs for high proficiency second language users was not replicated given that the mean switch cost from Korean to English ($M = 12.9$ ms) was significantly lower than the cost to switch from English to Korean ($M = 109.5$ ms).

There are several possible explanations that might account for this finding. The first variable that should be examined is the proficiency of the participants. The fact that the majority of participants (29/40) were PhD students in a major US university, with all but one of the others being MA students and Faculty/ post-doctorate researchers, supports the claim that these individuals were highly proficient in English. However, a likely explanation for the asymmetrical switch costs is that the participants in this study, despite documented success with graduate-level studies in English, had not reached the same level of L2 proficiency as participants in past bilingual language switch studies in which switch cost symmetry was reported. Performance on bilingual language switch tasks is influenced not just by language proficiency as measured by academic success and ability to speak English in school or work settings, but also extensive experience using both languages in the target language environment. The literature on cognitive control advantages for simultaneous bilinguals (e.g., Bialystok, 1999, 2007; Kovacs & Mehler, 2009) seems to suggest that experience is key in terms of using and controlling two languages over the course of the lifetime. It seems reasonable to suggest that when compared with the participants in Costa and Santesteban (10 highly-proficient Spanish-Catalan speakers in Spain), the participants in the pilot study, while highly proficient,

lacked the same degree of proficiency and experience using their L2 in an English speaking environment. While this issue was beyond the scope of the pilot study, the potential implications of language use and experience (above and beyond general standard measures of proficiency) make it an area of potentially valuable future research.

While reactive inhibition (Green, 1998) does offer a possible explanation for the switch cost asymmetry and for faster L1 naming latencies, it does not necessarily explain the fact that English stimuli in the mixed block were named an average of 126 ms faster than in the initial single-language block. In addition to inhibition and repetition-related effects, there may also have been a more general advantage for L2 lexical items. The data did not rule out the possibility that a more top-down effect also existed that further aided selection of L2 lexical items in addition to the inhibitory effects on the L1. This is also consistent with Green's IC Theory, particularly the claim that language task schemas provide a top-down influence on lexical selection.

RQ4: Is there a differential effect of repetition between L1 and L2 picture naming reaction times across blocks?

Hypothesis 4: Repetition effects for English stimuli will be larger than repetition effects for Korean stimuli.

This hypothesis was supported by the data. The second block of English pictures was named an average of 296 ms faster than the same pictures named the first time in block one. In contrast, the latency advantage for Korean pictures named in the second block was only 106 ms when compared to the initial Korean block. This finding was not

unexpected, especially considering the large difference in initial naming latencies for the two languages. However, this did represent an important consideration for research design with respect to the number of stimuli pictures to include as well as the number of comparisons required depending on the effect under investigation. Failure to account for differences in L1 and L2 repetition effects may negatively impact data and lead to potentially false conclusions.

RQ5: Does picture naming task switching performance correlate with performance in non-linguistic high/low and odd/even switch task?

Hypothesis 5: Switch costs from the picture naming tasks (English to Korean and Korean to English) will correlate significantly with performance on nonlinguistic task-switching.

Not only was this hypothesis not supported by the data, the correlations between picture naming switch performance and nonlinguistic task switching were strikingly low. There appeared to be no obvious relationship between linguistic and nonlinguistic task switching performance, at least as measured by the tasks utilized in the pilot study. This is in direct contrast to previous literature linking linguistic and nonlinguistic task switching through behavioral measures (e.g., Prior & MacWhinney, 2010) as well as brain research (e.g., Abutelebi & Green, 2007; Wang, Xue, Chen, Xue, and Dong, 2007).

RQ6: Does picture naming performance correlate with individual differences in working memory and cognitive control (Anti-saccade task).

Hypothesis 6: There will be a significant correlation between picture naming switch scores and Antisaccade percentage correct score.

Data from the pilot study did not support this hypothesis. Mirroring the results for the nonlinguistic task-switching task, there was no relationship observed between picture naming switch performance and the performance on the antisaccade task. The only correlation that approached significance was accuracy on the prosaccade condition with switch costs from Korean to English ($-.288, p = .076$). The correlation, while not significant, was a trend in the right direction as performance on the antisaccade task, representing an increased ability to inhibit distracting information, might also be related to inhibition of non-target lexical items. This raises more questions than answers, however, as performance on prosaccade conditions of antisaccade tasks has been shown to vary little across individuals as it measures a fairly stable prepotent response (Engle, 2002). What this might mean with regards to the potential influence of inhibitory control on linguistic task switching as measured by the antisaccade task is a question for future research if indeed significant correlations are found.

Overall, the absence of substantial correlations between picture naming switches and performance on the nonlinguistic switch task and antisaccade task made it very clear that, if general task switching and inhibitory processes do indeed overlap with their language-related counterparts as suggested in the literature, they do so in a manner that is far from straightforward. Once again, it seems likely that past experience actually using the language in communication (as opposed to a static measure of proficiency such as the

TOEFL or other written, grammar and vocabulary-focused assessment) would be a productive area in which to focus future research.

5.8 Conclusion

The following key results were obtained from the pilot study. First, L1 pictures named in single-language blocks were named faster than L2 pictures named in single-language blocks. This result supports the assertion that, while highly proficient in English, the participants in the pilot study were still Korean-dominant. In contrast to faster naming latencies for pictures named in single-language blocks, pictures presented in a mixed block were named faster in the L2 (English) than the participants' native Korean. This appears to provide further support for Green's (1998) Inhibitory Control Theory as it can be argued that the bilinguals had to overcome a higher degree of inhibition when naming Korean pictures, which resulted in longer naming latencies. While reactive inhibition, as postulated by Green's IC Theory, may be able to explain the naming latency difference between Korean and English pictures, an additional explanation is required to account for the significant speed-up of responses for English stimuli in the mixed condition. In addition to repetition-related effects, it is possible that a more top-down effect also existed that further aided selection of L2 lexical items in addition to the negative inhibitory effects on the L1. This is also consistent with Green's IC Theory, particularly the claim that language task schemas provide a top-down influence on lexical selection.

Unlike past research on picture naming switch performance, the highly proficient bilinguals in the pilot study demonstrated significant asymmetry of switch costs with

switches to English approximately 100 ms faster than switches from English into Korean. While unexpected, this result supports Green's (1998) Inhibitory Control Theory as the effect can be explained by the need to overcome more inhibition when switching to the more dominant L1. One possibility that seems to warrant further investigation is the role of experience in the development of task switching ability and any potential positive effects of bilingualism on cognitive control in general, and inhibitory control and task set switching more specifically. It seems likely that the category "high proficiency bilingual" is not sufficiently well-defined to enable comparison of switching performance across studies and that language history and language environment potentially play a major role in the development of cognitive control skills, at least as related to language-related inhibitory control and switching. The low correlations between picture naming switches and performance on the nonlinguistic switch task and antisaccade task suggest that the relationship between picture naming performance and related individual differences is not straightforward. This reinforces the need for future research on the effects of past experience actually using the language in communication and in environments in which both languages are used.

The purpose of the pilot study was to explore several key findings and assumptions related to picture naming studies such as Costa and Santesteban (2004). Specifically, the pilot study revealed picture naming reaction times in the L1 to be faster in a single-language block and L2 picture naming latencies to be faster in a mixed condition. Switch costs were examined and results showed a higher cost of switching into the L1 for highly proficient Korean and English bilinguals. This effect matches that found for low proficiency learners in past studies such as Costa and Santesteban (2004) and is

opposite of the effect reported for their high proficiency Spanish-Catalan bilinguals. Finally, differential effects of repetition were observed with L2 picture naming latency benefiting more than L1 naming reaction times. Individual differences in cognitive control were also measured to examine the influence of executive capacity and control on bilingual picture naming performance with no significant relationships detected.

6 Current Study

The literature reviewed in Chapters 2-4, in conjunction with the pilot study results reported in Chapter 5, leave several critical questions unanswered with respect to mix and switch costs in bilingual language processing. Major issues yet to be resolved include: 1) the degree to which mix and switch phenomena (e.g., switch cost asymmetry) commonly found in production tasks occur in differing contexts, such as receptive tasks with variable semantic loads, 2) the source of the L2 advantage (and apparent L1 disadvantage) in bilingual picture naming mixed conditions, and 3) the potential carry-over of mixed block L2 processing advantages to subsequent single language processing. Also, the role of general cognitive control in bilingual language switching, as well as its potential role as aptitude for second language acquisition, remains unclear. Based on the literature reviewed and the results of the pilot study, the following study was conducted to investigate these questions.

6.1 Study Overview

This study consists of three experiments designed to investigate mix and switch effects in bilingual language processing. Experiments 1 and 2 each include one bilingual picture naming task, one measure of general cognitive control (Simon Task), and one English proficiency measure (“Lexical Robustness” measure). Experiment 3 includes one lexical decision task, one semantic categorization task, the Simon Task, and the same measure of English proficiency. In addition to the core tasks for each experiment, participants in all experiments completed a demographic questionnaire.

Due to the large N size required for analysis of correlations between bilingual switch costs and individual differences in cognitive control (as measured by the Simon Task), data collection for Experiment 3 was conducted during the first two experiments. That is, instead of administering the lexical decision and semantic categorization tasks to approximately 30 participants in a stand-alone third experiment, the two tasks were integrated into the test procedure for Experiments 1 and 2. Administering the lexical decision and semantic categorization tasks to participants in the first two experiments created a total N size of 70 for these tasks. It is important to note, however, that although the lexical decision and semantic categorization tasks are listed in the general procedures of Experiments 1 and 2, results from these tasks (and correlations between task performance and individual differences in cognitive control) will be reported separately as Experiment 3.

Tasks for each experiment session are presented in Table 2, followed by a brief description of the tasks. The two picture naming tasks will be introduced first, followed by the lexical decision, semantic categorization, Simon Task, and proficiency measure.

Table 2. Task list for Experiments 1-3

Experiment 1	Experiment 2	Experiment 3
1. 5-Block Picture Naming Task	1. Go No-Go Picture Naming Task	1. Lexical Decision Task
2. Simon Task	2. Simon Task	2. Simon Task
3. Lexical Robustness Task	3. Lexical Robustness Task	3. Lexical Robustness Task
4. Lexical Decision Task*	4. Lexical Decision Task*	4. Semantic Categorization Task
5. Semantic Categorization Task*	5. Semantic Categorization Task*	

(* denotes Experiment 3 tasks)

Experiment 1 includes a bilingual picture naming task in a 5-block design. This task is nearly identical to the task used in the pilot study reported in Chapter 5, with the exception of 27 new pictures added to each of the final two blocks. As shown below in Figure 4, Blocks 1 and 2 are single-language blocks (Korean and English in this example, but the order was counterbalanced in the actual experiment), Block 3 is the critical mixed language block, and Blocks 4 and 5 are final single-language blocks (Korean and English, again counterbalanced).

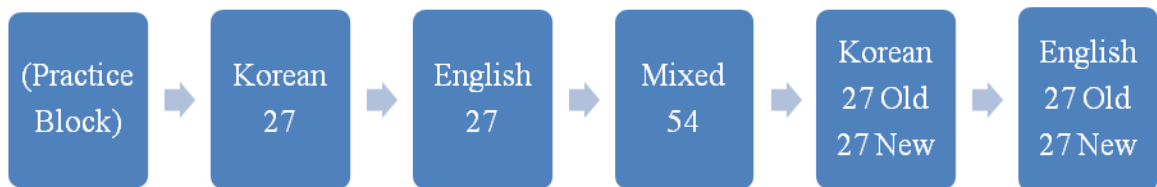


Figure 4. Bilingual Picture Naming Task 5-block design

In Experiment 1, the Korean and English pictures presented in the first two blocks are repeated in the mixed condition. The same pictures are then repeated a final time in Blocks 4 and 5 such that pictures named in Korean in Block 1 are named again in Block 4 (English pictures named in Block 2 are also named in Block 5). The purpose of this task is threefold. First, determine if switch cost asymmetry exists in the mixed block (replication). Second, determine if naming pictures for both languages in the mixed block creates the L2 RT advantage and L1 disadvantage commonly reported in the literature (replication). Finally, determine if the L2 advantage and L1 disadvantage carry over to subsequent single-language blocks following the critical mixed block (Blocks 4 and 5). If the L2 advantage continues into the subsequent single-language block, this would suggest that the mechanism underlying language switching in the mixed block is not simply reactive inhibition confined to the mixed language environment.

In addition to Block 1 and Block 2 pictures appearing again in the final two blocks, 27 new pictures are also presented for each language. The purpose of this manipulation is to determine whether the L2 advantage carries over to new pictures in the post-mixed block single language conditions. If the L2 advantage persists into the final single-language blocks in Experiment 1, this would suggest that the selection mechanism responsible for switches in the mixed block affects the L2 system as a whole, and not simply the specific lexical items named in the mixed block. That is, if inhibition underlies lexical selection in unbalanced bilinguals as previously reported (Costa & Santesteban, 2004), then this would suggest that inhibitory effects on the non-target language are global in nature and not limited to specific lexical items. One alternate explanation for the L2 mixed block advantage in this type of task is increased repetition effects for L2 items

compared with L1 items. The existence of an L2 advantage in a final single-language block for novel pictures would suggest that the effect is not simply the result of increased repetition effects for specific L2 items.

Experiment 2 utilizes a modified picture naming task to further examine the L2 advantage in bilingual language switching. Unlike the 5-block design used in Experiment 1, this task contains two single-language blocks and two mixed blocks of pictures (Figure 5). The critical element in this picture naming task is the inclusion of a Go No-Go manipulation, which requires participants to verbally name the pictures of only one target language in each of the two mixed-language blocks (with no verbal response to non-target language pictures). This manipulation is designed to determine if the L2 reaction time advantage commonly reported for mixed language conditions exists independent of response articulation. One possible explanation for the L2 advantage is that the language processor selects the weaker L2 as the default language as compensation in mixed language conditions. If this were the case, removing the need to articulate the competing L1 should nullify the L2 advantage. This can be determined by comparing mean reaction times for one mixed language block requiring only a L1 response with a mixed language block requiring only a L2 response. In addition, although only one response language is required for each of the last two blocks, switch costs can still be measured by comparing responses that follow same-language stimuli with responses that follow stimuli from the non-response language. For example, a response for a “Korean” picture (color-coded yellow) following another Korean response would be considered a non-switch trial, while the same picture following an “English” picture (color-coded blue) would be considered a switch trial.

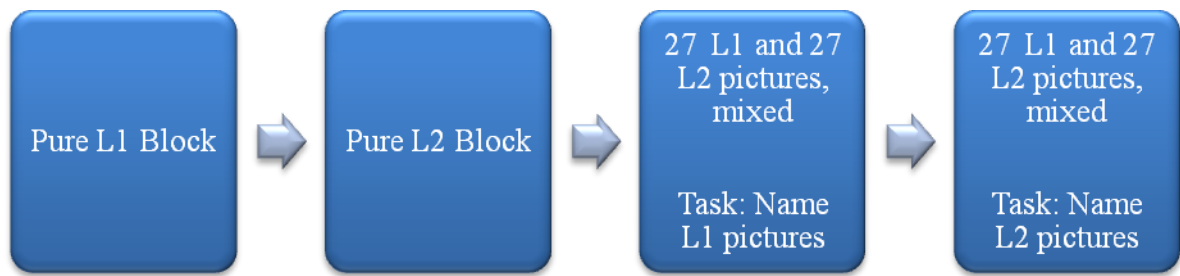


Figure 5. Go No-Go Picture Naming task block order

In addition to the picture naming task included in Experiments 1 and 2, each experiment includes a lexical decision task and a semantic categorization task (Experiment 3 tasks) to investigate the degree to which mix and switch costs commonly reported in production tasks also occur in non-production tasks with varying degrees of semantic involvement. Key questions include whether switch costs occur in the absence of language production (e.g., a lexical decision task) and if an increased semantic processing requirement affects the magnitude of mix and switch costs.

Finally, in addition to the four core tasks, two additional tasks are administered in each experiment. First, a computer-delivered Simon Task is administered to measure general inhibitory control ability. Second, a “lexical robustness” task (Gollan, Montoya, & Werner, 2002; Schweiter & Sunderman, 2008) is administered to measure participants’ vocabulary knowledge and to better estimate their English proficiency level.

The research questions for this study will now be presented, followed by a description of the methodology, results, and discussion for the three experiments in Chapters 7, 8, and 9.

6.2. Research Questions

This study was designed to investigate the following research questions:

RQ1. Does switch cost asymmetry exist when naming pictures in a mixed language condition (Korean and English) of a standard picture naming task?

RQ2. Do reaction times in the mixed block of picture naming tasks show an L2 reaction time advantage and L1 reaction time disadvantage for non-balanced bilinguals?

RQ3. Does the L2 reaction time advantage in the mixed block carry over to subsequent single-language block L2 picture naming?

RQ4. If the L2 reaction time advantage in the mixed block carries over to subsequent single-language block L2 picture naming, does the effect differ between previously named (old) and novel (new) pictures?

RQ5. Does the L2 reaction time advantage and L1 disadvantage persist in a Go-No Go variant of the picture naming task in which participants only verbally respond to one of the two languages?

RQ6. Do switch costs exist in a Go-No Go variant of the picture naming task in which participants only respond to one of the two languages?

RQ7. Does language switch cost asymmetry exist in Lexical Decision and Semantic Categorization tasks?

RQ8. Do reaction times in the mixed blocks of Lexical Decision and Semantic Categorization Tasks show an L2 reaction time advantage and L1 reaction time disadvantage for non-balanced bilinguals?

RQ9. Does the L2 RT advantage and L1 RT disadvantage carry over to subsequent single-language blocks in the Lexical Decision and Semantic Categorization Tasks?

RQ10. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual language switching tasks (Semantic Categorization and Lexical Decision)?

7 Standard Picture Naming Task (Experiment1)

7.1 Standard Picture Naming Task

Experiment 1 includes one main bilingual language processing task—a 5-block bilingual picture naming task— as well as one measure of cognitive control (Simon Task), and one English proficiency measure. With the addition of the two tasks added from Experiment 3 (Lexical Decision and Semantic Categorization), a total of five tasks were administered during the testing session. After a general overview of the experiment is provided, participant information, design, procedure, and results are presented and discussed.

The main task in Experiment 1, the Standard Bilingual Picture Naming Task, utilized a 5-block bilingual picture naming design to examine several issues related to mix and switch costs in bilingual language processing. The first purpose was to determine if switch cost asymmetry exists in a mixed picture naming condition for unbalanced bilinguals. The second goal was to determine if naming pictures for both languages in the mixed block created the L2 RT advantage and L1 disadvantage commonly reported in the literature (e.g., Phillip, Gade, & Koch, 2006). The third goal was to determine if the L2 advantage and L1 disadvantage carry over to subsequent single-language blocks following the critical mixed block. Finally, 27 novel pictures were included in each of the final single language blocks in order to determine if potential carry-over effects are dissociable from repetition effects. The purpose of this manipulation was to determine whether the mechanism(s) underlying bilingual language switching affects specific lexical items or the entire non-target language more globally. An L2 advantage for both old and novel pictures in the final single-language blocks would support the latter

explanation, while an L2 advantage for only old (not new) pictures would suggest a processing advantage limited to specific (i.e., previously processed) lexical items. It should be noted that this manipulation (i.e., old/new pictures) sets this study apart from past picture naming studies. To the author's knowledge, no previous study has included this design; therefore, results from this study represent novel findings in the study of mix and switch effects.

Experiment 1 was designed to investigate the following research questions:

RQ1. Does switch cost asymmetry exist when naming pictures in a mixed language condition (Korean and English) of a standard picture naming task?

RQ2. Do reaction times in the mixed block of picture naming tasks show an L2 reaction time advantage and L1 reaction time disadvantage for non-balanced bilinguals?

RQ3. Does the L2 reaction time advantage in the mixed block carry over to subsequent single-language block L2 picture naming?

RQ4. If the L2 reaction time advantage in the mixed block carries over to subsequent single-language block L2 picture naming, does the effect differ between previously named (old) and novel (new) pictures?

RQ5. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual language switching tasks?

Method

7.1.1 Participants

A total of 40 native speakers of Korean (19 male/ 21 female) who are proficient in English were recruited for this study. Participants were recruited from the University of Maryland campus community by printed advertisements (flyers posted on campus) as well as electronic postings on the University of Maryland Korean Graduate Student Association website. The breakdown of participant education levels is as follows: 7 undergraduate students, 27 graduate students, and 6 post-doctorate researchers/ visiting scholars. To avoid potential age-related influences on picture naming performance, only participants between the ages of 18 and 45 were recruited. The participants' ages ranged from 20-43 years old ($M_{age} = 31.6$, $SD = 5.9$), and the average age at time of arrival to the United States was 25.2 years ($SD = 5.1$). No participant arrived in the United States or lived in a predominately English-speaking country before the age of 15. Time in the United States ranged from 2 to 16 years ($M = 6.1$, $SD = 3.9$), and the average age at which English education began in Korea was 11.5 years ($SD = 2.8$).

7.1.2. Design

The picture naming task consisted of a total of 5 experimental blocks in addition to an initial practice block (as presented in Figures 6 and 6a). The experimental blocks were presented in the following order for the first group (lists were counterbalanced so that the English block occurred first for half the participants);

1. All Korean (yellow; 27 pictures)
2. All English (blue; 27 pictures),

3. Korean and English Mixed (mixed; 54 pictures),
4. All Korean repeated (27 old; 27 new Korean pictures)
5. All English repeated (27 old; 27 new English pictures)

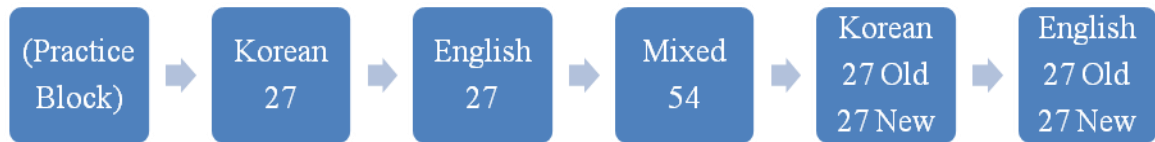


Figure 6. Group 1 example block order

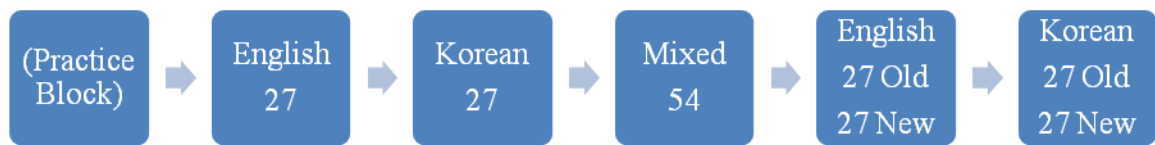


Figure 6b. Group 2 example block order

In the practice block, participants were instructed that pictures with a blue background were to be named in English. They then completed 5 trials in which pictures with a blue background appeared. Participants also completed one familiarization set of Korean-only responses (yellow background).

The Mixed Block in this task utilized the task-cuing paradigm (see Kiesel et al., 2010, for review), in which participants name pictures in either Korean or English based on a color cue. In this block, designed to measure mix and switch costs, pictures were ordered such that 1, 2, or 3 pictures of a single color occurred consecutively before a switch to the other language (see Appendix A for mixed block order).

Stimuli in the mixed block condition were counterbalanced such that each critical stimulus picture was named in Korean by half of the participants and English by the other half. The stimuli were further counterbalanced such that each stimulus picture occurred

as a switch trial for half of the participants and as a non-switch trial for the other half (with the exception of 2 pictures that occurred as switch trials across lists due to inherent ordering constraints).

Each of the 54 old pictures was named a total of three times during the experiment. Each of the twenty-seven pictures in the Korean set was named once in the initial all-Korean block (random order), once in the mixed block (fixed order), and once in the repeated Korean block (random order). The English pictures were also named a total of 3 times during the experiment; once during each of the all-English blocks and once during the mixed trials. In addition, the 54 new pictures were presented in the final two naming blocks (27 new Korean pictures, 27 new English pictures). These pictures were named only one time in their respective final language block.

7.1.3 Materials

The materials for this task include the same type of stimuli pictures used in the pilot study reported in Chapter 5. One hundred eight (108) line drawing pictures of common objects were selected from the University of California, San Diego's International Picture Naming Project database (Szekely et al., 2004) and divided into two sets of 54 pictures (Sets A and B), matched for syllable count ($M = 1.5$) and log frequency ($M = 2.98$) based on the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993). Each set, A and B, was then divided into 2 sub-lists (A1, A2, B1, B2), with each sub-list also matched for length and frequency. These four lists allowed for counterbalancing based on the following factors: Language (English or Korean) and Novelty (Old or New pictures).

Mixed Block stimuli were counterbalanced so that pictures occurring as switch trials for half the participants occurred as non-switch trials for the other half. The order of language block presentation was also balanced across participants (i.e., half of the participants started with Korean as Block 1 and half started with English).

One set of 54 pictures was presented with a blue background that indicated the pictures were to be named in English. The second set of 54 pictures was set on a yellow background, which signified that the pictures were to be named in Korean.

In addition to the two sets of critical items, one additional set of 10 pictures was developed for a practice block in which participants were familiarized with the picture naming procedure (5 practice items for each language). These items were not scored.

7.1.4. Scoring and Analysis

High and low cut-off points for reaction times were set at 300ms and 3000ms. Responses with reaction times falling outside of this range were discarded. The participant mean and standard deviations were then computed, and values +/- 3 SDs from the mean were also removed. Voice responses were coded according to the following scoring system:

1. Correct
2. Liberal correct (e.g., “dog” for the target “wolf”)
3. Error (no response, or wrong response in correct language)
4. Language error (correct or incorrect response in wrong language)
5. Technical error (equipment problem) or extraneous noise (causing early RT capture)

Answers judged as “liberal correct” were scored as correct if all responses (e.g., two single-language blocks and one mixed block) were the same. For example, the response “dog” was scored as a correct response for the stimulus “wolf” due to ambiguity in the line drawing picture.

After scoring, data from incorrect responses were removed from the dataset. Altogether, removal of incorrect responses, outliers, and technical errors affected approximately 9.5% of the data for this task.

After preparation of the response data, a repeated measures ANOVA was conducted to investigate potential differences between mean picture naming reaction times for the initial single language blocks as well as differences between Mixed Block Korean and English means.

Mix costs were calculated by subtracting the Mean RT for the initial single language block from the Mean RT of non-switch Mixed Block pictures for both Korean and English. A 2 (Language) x 2 (Condition) repeated measures ANOVA was then conducted to examine potential differences in mix effects.

Switch costs were examined by subtracting non-switch trial RTs from switch trial RTs within the mixed language block. A 2 x 2 repeated measures ANOVA was used to compare mean L1 to L2 switch costs with L2 to L1 switch costs to determine if asymmetry exists.

In order to measure repetition effects, a 2 x 2 repeated measures ANOVA was conducted with 2 factors: Language (Korean and English) and Repetition (first or second single-language block presentation of stimuli picture). This analysis was conducted in

order to reveal potential main effects of language and repetition as well as possible interaction effects (e.g., L2 benefiting more from repetition than L1).

Reaction times for final block novel pictures were compared to reaction times for final block old pictures (i.e., pictures that were previously named in the initial single language block and mixed block). A repeated measures ANOVA was used to examine potential differences in repetition effects.

Finally, correlations were examined between bilingual picture naming performance and inhibitory control ability as measured by the Simon Task.

7.1.5 Procedure

After providing informed consent, participants completed a Demographic Information and Language Use survey (Appendix I). This survey elicited information about participant language history as well as current use of L1 (Korean), L2 (English), as well as any other languages known.

Participants were tested individually in a quiet room on a Dell laptop computer with a 15" LCD monitor. The picture naming task was presented first using E-Prime 2.0 (PST, Pittsburgh, PA) and, in addition to reaction time data collected in E-Prime, voice responses were recorded with a Sony digital recorder. Participants spoke into an Audio-Technica AT20 microphone secured in a microphone stand and positioned in front of their mouth in a manner that was comfortable and did not obstruct the participants' view of the computer screen. After the picture naming task, participants completed two receptive language processing tasks, a lexical decision task, and a semantic categorization task. These measures are Experiment 3 tasks and are detailed in Chapter 9.

After completion of all three bilingual language processing tasks, participants completed a computer-delivered Simon Task, presented using E-Prime 2.0 (PST, Pittsburgh, PA), and a Lexical Robustness task, which was administered by the researcher. These tasks were followed by a short exit interview in which participants were asked about any strategies used to complete the tasks in order to identify any unintended influences on their performance. Once all the tasks were completed, the participants were debriefed, paid \$15, and thanked for their participation. Participants had the opportunity to ask questions about the study before they left the testing station. Testing sessions averaged 1 hour, 20 minutes.

7.1.6 Results

Overall, mean accuracy for English pictures was 91%, and mean accuracy for Korean pictures was nearly 97%. One participant was removed completely from analyses due to low picture naming accuracy (e.g., a block mean of 30%, mostly resulting from space bar responses). Therefore, the total number of participants included in analyses for this task was 39. An overview of Standard Picture Naming Task mean reaction time results is presented below in Table 3.

Table 3. Standard Picture Naming mean RTs by block and trial type

1 st Block Korean	1 st Block English	Mixed Block Korean		Mixed Block English		2 nd Block Korean		2 nd Block English	
1186	1308	1205		1089		1088		1161	
		NonSW	SW	NonSW	SW	Old	New	Old	New
		1152	1264	1060	1122	963	1218	982	1363

NonSW = non-switch; SW = Switch

The mean reaction time for correct responses in the first English block was 1308.1 ms ($SD = 202.1$) and the mean reaction time for the first Korean block was 1186.8 ms ($SD = 219.3$). A repeated measures ANOVA showed this difference to be significant ($F(1, 38) = 13.18, p = .001$; $F(1, 104) = 40.76, p < .001$).

In contrast to the faster reaction times for Korean (L1) pictures in single-language blocks, the mean reaction time for correctly named Korean pictures ($M = 1205.6, SD = 200.9$) was slower than English pictures ($M = 1089.8, SD = 146.6$) in the critical mixed block. Analysis of variance showed the difference to be significant ($F(1, 38) = 30.33, p < .001$; $F(1, 104) = 22.94, p < .001$). To illustrate the differences between the initial single language blocks and the mixed block, mean reaction times for each block of the Standard Picture Naming Task are presented in figure 7.

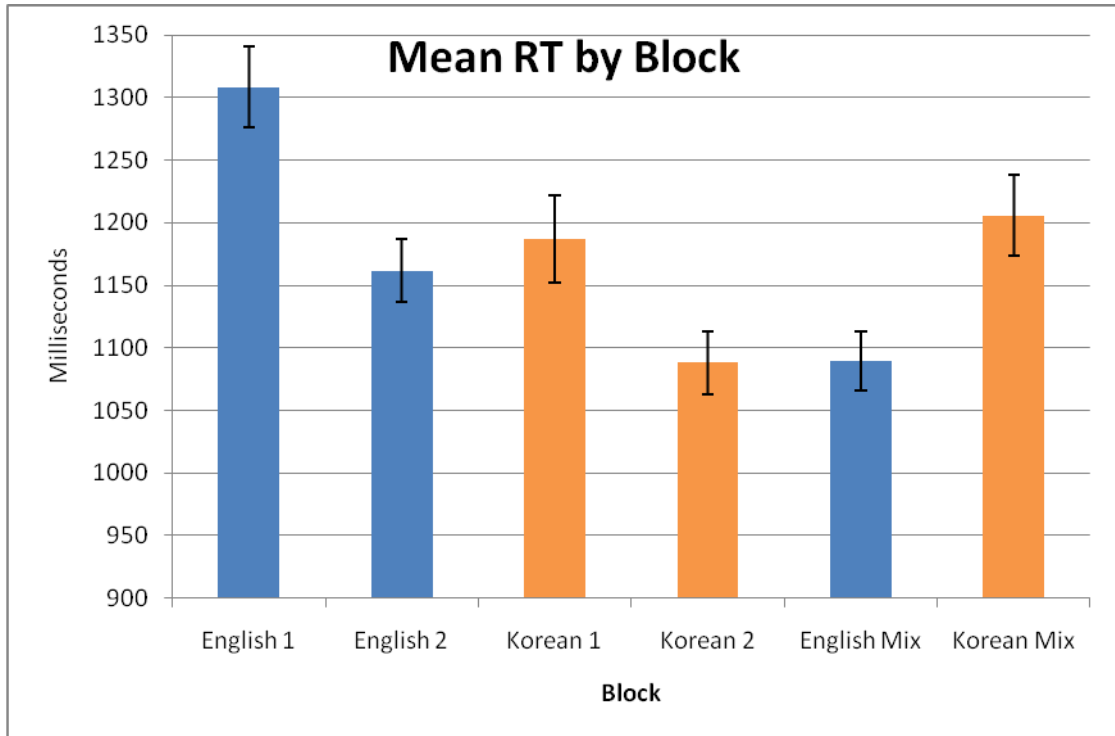


Figure 7. Picture Naming Task mean reaction times by block and language

In addition to differences in mean block naming latencies, the costs associated with mixing stimuli in the critical Mixed Block also differed by language. Mix costs were calculated by subtracting the Mean RT for the initial single language block from the Mean RT of non-switch Mixed Block pictures for both Korean and English. Analysis of Variance revealed a significant difference ($F(1,38) = 28.67, p < .001$; $F(1, 104) = 48.83, p < .001$) between Korean ($M = -34.9$ ms, $SD = 244.3$) and English ($M = -269.8$, $SD = 244.1$) mix costs. Comparing the initial single language block means with means for non-switch trials in the Mixed Block, A 2 (Language) x 2 (Block) Repeated Measures ANOVA showed a non-significant main effect of language ($F(1,38) = .498, n.s.$; $F(1,105) = 3.19, n.s.$), but a significant effect for Block ($F(1,38) = 41.01, p < .001$; $F(1,104) = 81.28, p < .001$) and a significant interaction between Language and Block

($F(1,38) = 28.66, p < .001$; $F(1,104) = 48.83, p < .001$). Mean reaction times by language and trial type are presented in Table 4.

Table 4. Standard Picture Naming Task mixed block mean reaction times

Mixed Block English	Mixed Block Korean	Mix BK ENG Nonswitch	Mix BK ENG Switch	Mix BK KOR Nonswitch	Mix BK KOR Switch
1089.8 (146.6)	1205.6 (200.9)	1060.0(149.5)	1122.2(161.5)	1152.3(203.1)	1264.0(217.6)

The mean reaction time for correctly named Korean (non-switch) mixed block pictures ($M = 1152.3$ ms, $SD = 203.1$) was approximately 35 ms faster than the mean in the initial all-Korean block ($M = 1186.9$ ms, $SD = 219.3$). This difference was not significant ($F(1,38) = 1.03, n.s.$; $F(1,104) = 2.14, n.s.$). However, English Mixed Block reaction times were markedly faster than the initial all-English block RTs. This 248 ms difference between the all-English Block 1 mean RT ($M = 1308.1$ ms, $SD = 202.1$) and the mix block English non-switch mean RT ($M = 1060.0, SD = 149.5$) was significant ($F(1,38) = 101.05, p < .001$; $F(1,104) = 128.26, p < .001$) and demonstrates a robust processing advantage for correctly named English pictures in the mixed language condition. To illustrate this point, switch costs and Mixed Block mean reaction times (by trial type) are presented in Table 5 and Figure 8 below.

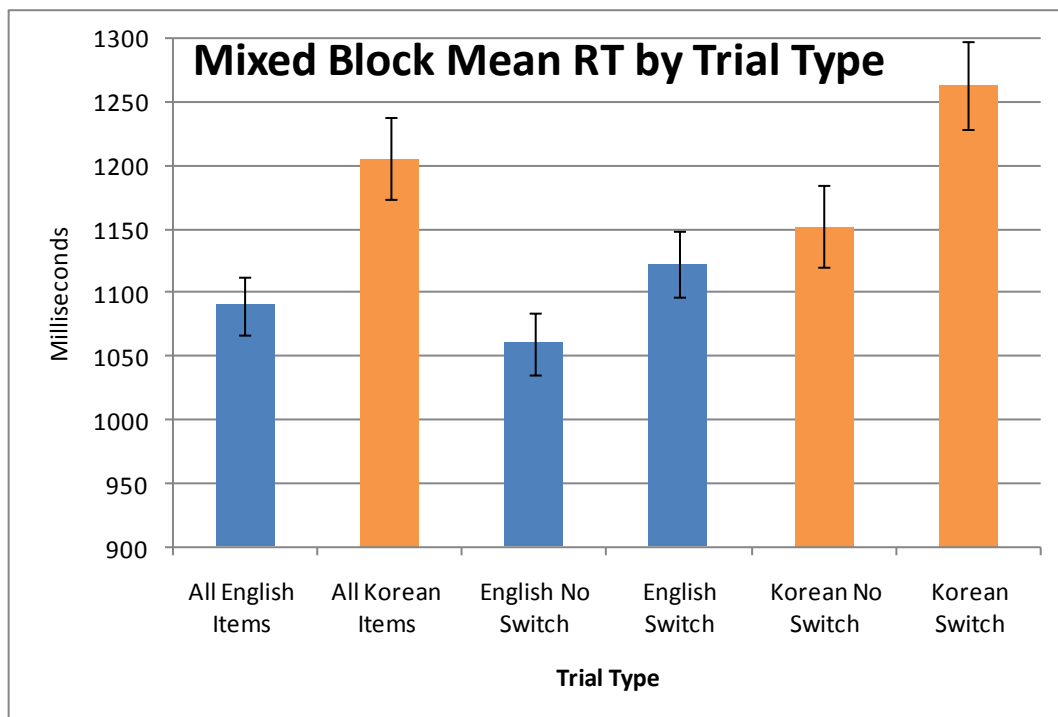


Figure 8. Picture Naming Task mix block reaction times by trial type

Examining switch costs for each language (Mix Block switch mean RT minus Mix block non-switch mean RT) revealed asymmetric switch costs with an average English switch cost of 62.25 ms ($SD = 102.7$) and average Korean switch cost of 111.62 ms ($SD = 123.2$).

Table 5. Standard Picture Naming Task switch costs

English Switch Costs	Korean Switch Costs
62.25 ms ($SD = 102.7$)	111.62 ms ($SD = 123.2$)

While language switching negatively affected picture naming performance in both languages, the reaction time cost was greater when switching into the participants' first language. The difference in switch costs was analyzed using a 2 x 2 ANOVA with the

factors “Language” (Korean and English) and “Trial Type” (switch and non-switch). The main effects of Language ($F(1,38) = 31.14, p < .001$; $F(1,104) = 23.76, p < .001$) and Trial Type ($F(1,38) = 38.24, p < .001$; $F(1, 104) = 20.75, p < .05$) were significant. The F1 analysis for the interaction of Language and Trial Type also reached significance ($F(1, 38) = 4.06, p < .05$), but the F2 analysis for the interaction of Language and Trial Type did not ($F(1,104) = .596, n.s.$). Switch cost data are presented graphically in Figure 9.

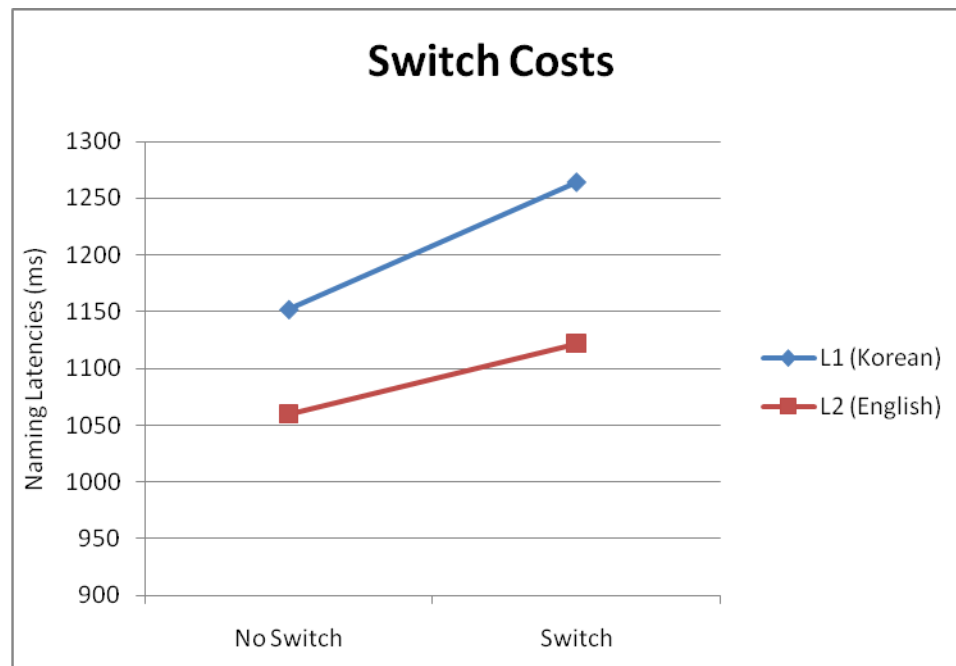


Figure 9. Picture Naming Task switch effects

The final analysis conducted on picture naming performance examined the mean reaction times for the last two blocks. Final single language block means are shown in Table 6.

Table 6. Standard Picture Naming Task mean RTs for final block items

	<i>Final Block All English</i>	<i>Final Block All Korean</i>	<i>Final BK Old English</i>	<i>Final BK New English</i>	<i>Final BK Old Korean</i>	<i>Final BK New Korean</i>
Mean RT	1161.8 (154.3)	1088.1 (156.5)	982.4 (157.7)	1363.8 (189.1)	963.2 (162.1)	1218.2 (172.8)

Data addressing RQs 1 and 2 showed faster reaction times for Korean compared with English in the initial single language blocks and a reverse effect, with English faster than Korean, in the mixed block. The final single language blocks (the second all-Korean and all-English blocks) resemble the initial single language blocks, with a faster overall mean RT for Korean items ($M = 1088.1$, $SD = 156.5$) compared to the mean RT for English items ($M = 1161.8$, $SD = 154.3$). ANOVA shows this difference to be significant ($F(1, 38) = 17.37$, $p < .001$; $F(1, 104) = 26.33$; $p < .001$). Based on this initial analysis, it would appear that the L2 (English) Mixed Block processing advantage does not carry over to the final single language blocks. However, further analysis reveals differences between previously named (old) and novel (new) pictures in the final single language blocks for both Korean and English.

Examination of RTs for correctly named novel pictures (i.e. not previously named or seen by participants) shows a pattern similar to the overall initial and final block reaction time means, with Korean pictures named faster than English pictures. The mean reaction time for novel Korean pictures in the final block was 1218.2 ms ($SD = 172.7$), and the mean RT for novel English pictures was 1363.8 ($SD = 189.1$). Analysis of variance confirms that this difference is significant ($F(1, 38) = 34.98$, $p < .001$; $F(1, 104) = 46.45$, $p < .001$). In contrast to these results, there was no significant difference in reaction times between Korean ($M = 962.3$, $SD = 162.1$) and English pictures ($M = 982.4$,

$SD = 157.7$) that had been previously seen and named during Block 1 and the Mixed Block ($F(1, 39) = .927$, n.s.; $F(1,104) = 2.64$, n.s.). These results are presented below in Figure 10.

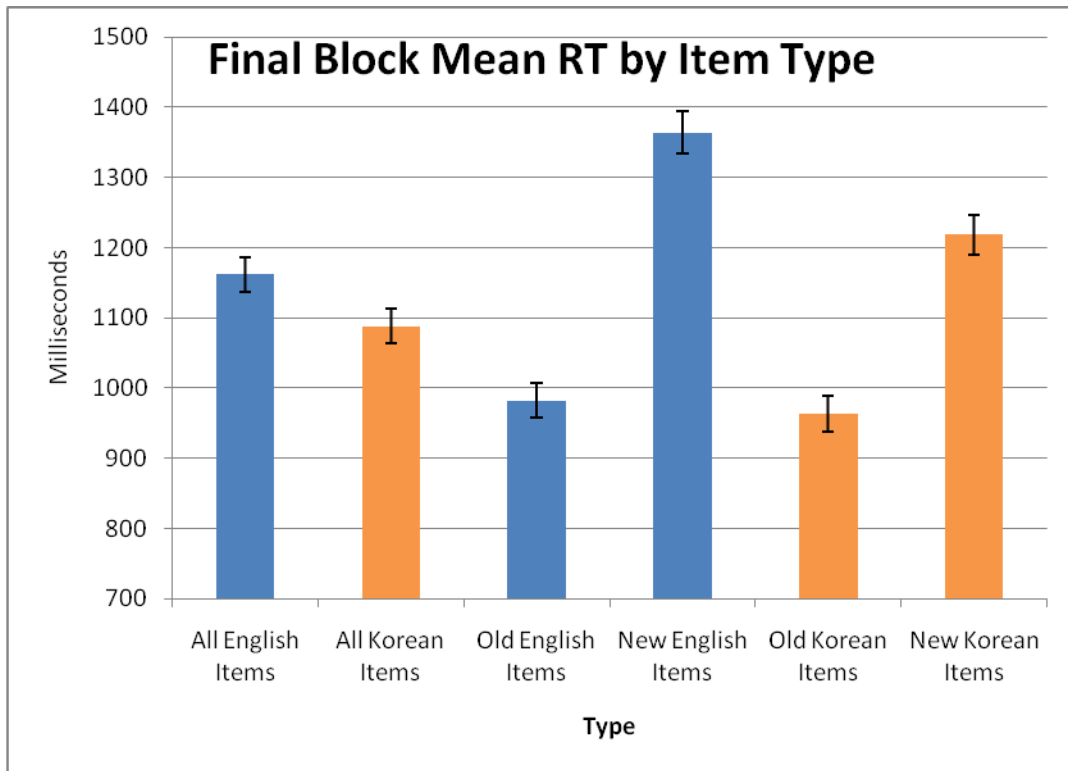


Figure 10. Final block mean reaction times by trial type

Analyzing the differences in mean reaction times between old and new items shows significantly faster reaction times for old items in both languages. The mean reaction time for old Korean pictures was 963.2 ms ($SD = 162.1$), while the mean RT for new pictures was 1218.2 ms ($SD = 172.7$). This difference is significant ($F(1, 38) = 217.14$, $p < .001$; $F(1,104) = 142.99$, $p < .001$). Similarly, old English pictures ($M = 982.4$, $SD = 157.7$) were named significantly faster ($F(1,38) = 255.55$, $p < .001$; $F(1,104) = 231.54$, $p < .001$) than new English pictures ($M = 1363.8$, $SD = 189.1$). A 2

x 2 Repeated Measures ANOVA was conducted with the factors “Language” (Korean and English) and “Stimuli Type” (Old and New). The main effect of Language was significant ($F(1,38) = 19.19, p < .001$; $F(1,104) = 37.17, p < .001$), as was the main effect of Stimuli Type ($F(1,38) = 352.83, p < .001$; $F(1, 104) = 276.64, p < .001$) and the interaction of Language and Stimuli Type ($F(1,38) = 27.09, p < .001$; $F(1, 104) = 24.29, p < .001$).

Finally, a 2 x 2 Repeated Measures ANOVA with the factors Language and Block was conducted to analyze the overall repetition effects between the first and last single language blocks. The main effects of Language ($F(1,38) = 17.83, p < .001$; $F(1, 104) = 90.5, p < .001$) and Block ($F(1,38) = 68.71, p < .001$; $F(1,104) = 48.96, p < .001$) were significant. The participant interaction failed to reach significance ($F(1,38) = 3.12, p = .085$), but the interaction by items did ($F(1, 104) = 8.87, p < .001$).

7.2 Simon Task

The Simon Task was used as a measure of general cognitive control. In the Simon task, red and blue boxes were presented on the computer screen in one of three possible locations (center, left, and right). Participants were instructed to push the left TAB key (color coded blue) when the box presented on the screen was blue and the right TAB key (color coded red) when the box was red, regardless of where the box appeared on the screen. Three trial types were possible: congruent, incongruent, and neutral. In congruent trials, the location of the box on the screen matched the side of the keyboard for the appropriate response. For example, if told to press the left TAB key when a blue box appeared, a trial was congruent when a blue box was presented on the left side of the screen. The second trial type is incongruent. Incongruent trials occur when the colored

box was presented on the side of screen opposite of the correct keyboard response. For example, a blue box presented on the right side of the screen, which required a left TAB key response, represents an incongruent trial. Finally, neutral trials are trials in which the stimulus box is presented in the center of the screen.

With regard to planned analyses involving the Simon Task, it is important to note that correlations generally require data sets with an N size greater than the current study ($N = 40$). The Simon Task was administered to all participants of Experiment 1 and 2 with the goal of analyzing potential correlations between cognitive control ability and the two receptive tasks administered in Experiment 3 (Semantic Categorization and Lexical Decision, both with $N = 70$). Correlations were also conducted on data from Experiment 1 and 2 tasks, however, with the justification that data from this limited data set might still contribute the planning of a future, larger-scale study focusing on the potential influence of individual differences in cognitive control on second language processing.

7.2.1 Scoring

The reaction time difference between congruent and incongruent trials is termed the “Simon effect” (Simon & Rudell, 1967). In this task, the score represents the participant’s ability to inhibit prepotent responses based on stimuli location, and has been interpreted as an indicator of an individual’s general inhibitory control ability. Therefore, the RT difference score between congruent and incongruent trials was computed and was used as a measure of participants’ inhibitory control ability in order to investigate the possible connection between language switch performance and general cognitive control.

Only correct responses were counted, and scores above or below 3 standard deviations were removed the analysis. After scoring was complete, a correlation was run between participant Simon Scores and switch and mix costs incurred during the Standard Picture Naming task.

7.2.2 Results

Participants reported little difficulty with the Simon Task. The mean accuracy for the 40 participants tested was nearly 98% (range 92-100%), and the mean Simon Effect was 34 ms ($SD = 25.1$). Although the mean Simon effect reflected generally slower responses for incongruent responses compared to congruent, the actual effect varied greatly between participants. The greatest slowdown observed was approximately 84 ms, but several scores reflected little to no change between conditions. Two participants of the forty tested demonstrated slightly faster reaction times for incongruent stimuli, but the effect was relatively small in both cases (range = -12 to -15ms).

Correlations were examined between participant Simon Task scores and mix and switch costs for both Korean and English stimuli. No significant correlations were found when calculating correlations between Simon Task scores and 1. Korean switch costs, 2. English switch costs, 3. Korean mix costs, and 4. English mix costs.

Based on previous language processing and aptitude studies detailed in the literature review, it is possible that a link may exist between general cognitive control ability and language control required in bilingual processing tasks. If this were the case, one might expect to see significant correlations between performance on the Simon Task and mix and switch costs in the Standard Picture Naming Task. More specifically,

individuals with higher mean Simon Effect scores, which reflect a relatively poorer ability to overcome prepotent responses, might be expected to demonstrate greater switch costs in the Standard Picture Naming Tasks. Therefore, a direct relationship between non-linguistic, more general cognitive control ability (as measured by the Simon Task) would appear as a positive correlation with language switch effects. That is, individuals who demonstrate relatively greater difficulty overcoming prepotent responses in the Simon Task might also be expected to demonstrate relatively greater difficulty overcoming the prepotent tendency to respond in the dominant L1 when forced to switch to a less dominant L2. However, no significant correlations were found between Simon Task performance and switch costs in the picture naming task. In fact, no correlations neared significance for any of the four correlations run. The largest effect, and closest to (but still far from) significant result was the correlation between Simon Task scores and Mixed Block Korean mix costs (.217, $p = .184$). Based on the relatively small sample size, however, these results were not unexpected. The existence of a stable Simon Effect (+84 ms) signals that the measure worked as intended, and might serve as an appropriate measure of cognitive control in future, larger-scale studies.

7.3 Lexical Robustness Measure

The verbal proficiency measure included in this study was adapted from Schwieter & Sunderman (2008) and was designed to provide a measure of participants' vocabulary knowledge. This measure, based on the experimental procedures of Gollan, Montoya, and Werner (2002), is described as a method of operationalizing the "robustness of the L2 lexicon" (Schwieter & Sunderman, p. 223). Costa et al. (2006) also

refer to “lexical robustness” and defined it as the familiarity with and frequency of access that leads to greater automaticity of lexical retrieval. The task was verbally administered to the participant by the researcher, who provided a category for which the participant provided (orally) as many examples as possible in one minute. There were a total of ten categories, and the total score was calculated by adding the number of all correct responses to determine an overall score. Duplicate answers and answers outside of the required category were not counted toward the final score.

The verbal fluency measure was included in this study for two reasons. First, the number of category-specific items an individual can produce within one minute could be used as additional information to better estimate participants’ vocabulary knowledge. While this measure does not provide a full measure of a participant’s global L2 proficiency, it does produce useful information that, when combined with data from the language history questionnaire, provides a reasonable estimation of L2 vocabulary knowledge in a short period of time. Second, Schweiter and Sunderman (2008) used this measure to investigate where along the continuum of lexical robustness participants moved from reliance on inhibitory control to more language-specific processing. As the research questions of the current study overlap significantly with the core questions in Schweiter and Sunderman’s (2008) investigation into bilingual language selection, the use of the same proficiency measure for a different population may produce useful data for future studies on this issue.

A total of 40 participants completed this task, and the mean final score was 148 ($SD = 24.3$). Lexical Robustness scores varied greatly between the participants, with a minimum score of 99 and a maximum score of 201. This extreme variation was

somewhat unexpected for two reasons. First, participants were selected for participation in this study based on fairly standard criteria in terms of English proficiency. Second, and somewhat more surprising, there was no apparent relationship between Lexical Robustness scores and education level (e.g., undergraduate students vs. post-doctorate fellows), nor was there a significant relationship between Lexical Robustness scores and time in the United States. Data from the demographic questionnaire did reveal one striking relationship, however. The average age at which participants began learning English in Korea was approximately 11.5 years ($SD = 2.8$). The correlation between starting age for English language education (in Korea) and Lexical Robustness scores was $-.499$ ($p < .001$). As will be discussed later, the strength of this correlation remained impressively high when including all 70 participants who participated in this research project (correlation = $-.401$, $p = .001$). The relationship between English starting age and Lexical Robustness scores in Experiment 1 was larger than expected, especially considering the relatively small $N =$ size. Unfortunately, it was impossible to control for English start time while recruiting participants, and the more commonly used recruiting criteria (i.e., education level and time in the United States) did little to ensure a relatively homogenous sample in terms of English proficiency. Possible effects of this variation in proficiency will be addressed in the general discussion.

7.4 Discussion

The results from each task will be discussed in relation to this experiment's five research questions and hypotheses.

Research Question 1: Does switch cost asymmetry exist when naming pictures in a mixed language condition (Korean and English) of a standard picture naming task?

Hypothesis 1: Yes, mean reaction times will be higher for switches into the L1 than switches into the L2.

Past switch studies have demonstrated consistent asymmetric switch costs for non-balanced bilinguals performing picture naming tasks (e.g., Costa & Santesteban, 2004; Costa et al., 2006; Meuter & Allport, 1999; Schwieter & Sunderman, 2008). Results from the pilot study reported in Chapter 5 provide further support for expected switch cost asymmetry for participants in the current study. Based on consistent asymmetric switch cost for non-balanced bilinguals in the literature and similar results from a pilot study targeting the same population as the current study, it was expected that participants in the current study would also demonstrate asymmetric switch costs during the bilingual picture naming task.

Results from the current study are consistent with the pilot study and past studies showing asymmetric switch costs for non-balanced bilinguals. Examination of switch costs for each language revealed asymmetric switch costs with an average English switch cost of 62.25 ms ($SD = 102.7$) and average Korean switch cost of 111.62 ms ($SD = 123.2$). Both languages were negatively affected by switch trials, but the reaction time cost was greater when switching into the participants' first language. A 2 x 2 ANOVA with

the factors “Language” (Korean and English) and “Trial Type” (switch and non-switch) showed significant main effects for language, trial type, and a significant F1 interaction effect.

The non-significant F2 Language and Trial Type interaction likely resulted from greater variation in reaction times among the 108 picture stimuli used in this study. Whereas the mean log frequency of items used in this study was approximately 3.0, the actual log frequency range for items spanned from .69 (stroller) to 5.68 (car). It is therefore likely that reaction time responses for relatively low frequency items would differ from the higher frequency words. It is also likely that this greater variation might negatively affect F2 item analyses, and even potentially lead to a non-significant result when a more homogenous stimuli set may have resulted in a significant F2 effect. Based on this reasoning, the non-significant result for the F2 Language x Trial interaction should not negate the significant main effects (F1 and F2) of Language and Trial, or the significant F1 interaction effect for Language and Trial.

Based on the results addressed to this point, data from the Standard Picture Naming task provide additional evidence for asymmetric switch costs for non-balanced bilinguals. As was the case in the pilot study, there results are in line with predictions of Green’s (1998) Inhibitory Control Model. That is, higher switch costs from the second language to the more dominant first language in this study can be explained by the need to overcome higher levels of inhibition for L1 items.

RQ2. Do reaction times in the mixed block of the picture naming task show an L2 reaction time advantage and L1 reaction time disadvantage for non-balanced bilinguals?

H2: Yes. Reaction times for correct L2 responses will be faster than reaction times for L1 items in the mixed block condition of the bilingual reaction time task.

H2.1: Reaction times for correct L1 picture naming responses will be faster than L2 pictures in the first two single-language blocks.

Results of the pilot test demonstrated a clear L1 reaction time advantage in single language-block picture naming. That is, L1 pictures named in the initial single language block were named faster than L2 pictures in the initial single language L2 block. In contrast to the faster reaction times for Korean (L1) pictures in single-language blocks, the mean reaction time for correctly named Korean pictures was slower than English pictures in the critical mixed block. In addition to the differences in mean naming latencies, the costs associated with mixing stimuli also differed by language. A significant difference existed between mix costs with Korean stimuli named more slowly in the mixed condition and English stimuli named faster in the mixed condition. This difference revealed a striking contrast with L1 picture naming seemingly negatively affected by the mixed condition (named more slowly), while L2 picture naming clearly benefited from the mixed environment

Based on the previous literature on mix costs in bilingual picture naming (e.g., Christoffels et al., 2006; Kroll, Michael, Tokowicz, and Dufour, 2002; Phillip, Gade, & Koch, 2006) and results of the pilot study, reaction times for correctly named L2 pictures in the mixed block for this task were expected to be faster than correctly named L1 pictures in the mixed block. Also, L1 single-language block mean RTs were expected to

be faster than single-language L2 block RTs. Both of these predictions were supported by the data.

In the current study, mean reaction time for correct responses in the first English block was significantly slower than the mean reaction time for the first Korean block. This difference provides additional evidence that L1 picture naming performance in single-language blocks is faster than L2 picture naming in single-language blocks. When picture stimuli are named separately (i.e., not mixed together in the same block), L1 pictures are consistently named significantly faster than L2 (or weaker language) pictures. These results are consistent with predictions of the study as well as the extant literature.

Based on the results of the pilot test and the current study, it is possible to conclude that naming pictures in a mixed block environment results in an L2 advantage and L1 disadvantage for non-balanced bilinguals. However, while the benefit to L2 processing is very clear, the notion of an L2 disadvantage does not appear to be supported by the data. A quick look at the mean reaction times for each block in this study appears to reveal an inversion of processing advantage, with L1 pictures named faster in single language blocks and L2 pictures named faster in the mixed block. However, the fact that processing of L2 pictures in the mixed block speeds up significantly in the mixed block does not necessarily mean that L1 picture naming in the same block is significantly slowed as a result of the mixed language environment. In fact, the mean reaction time for Korean pictures was approximately 34 ms faster in the mixed block for non-switch items compared with the initial all-Korean block (switch items were excluded to avoid confounding mix and switch effects). While this difference does not represent a

significant speed up, it does not represent a significant slowdown either. If an L1 processing disadvantage did exist in the mixed block, one would expect a slower mean reaction time for non-switch mix block items compared with initial single-language block reaction times. The data from this study show no such disadvantage.

What is evident from this data set is a robust processing advantage for English items in the mixed condition compared with English items in the initial single language blocks. The speed up of almost 250 ms for English items in the mixed block is large enough to cause L2 mixed block items to be named faster than L1 items on average. Therefore, instead of a simple L1 advantage/ L2 disadvantage explanation for Mixed Block picture naming, results from this study suggest an explanation that involves a robust L2 processing advantage and either no effect for L1 items, or a minimal effect that did not reach statistical significance in this study. One explanation for these results can be found in an already extensively-studied phenomenon associated with repeated processing of identical or similar items: repetition priming.

Enhanced processing for repeated items is well established in the literature (e.g., Bajo & Canas, 1989; Ferrand, Humphreys, & Segui, 1998; Hernandez & Reyes, 2002; Wheeldon & Monsell, 1992). Furthermore, comparing the effects of repetition priming in bilingual language tasks has demonstrated larger repetition effects for the weaker language (Hernandez, Bates, and Avila, 1996). Depending on the design of the task then, unequal priming effects might contribute to the processing advantage for L2 stimuli in a mixed block condition. Applying priming-related findings to the design of the current study, one would expect to see a decrease in reaction times for all items repeated across two or more blocks. In other words, the mean reaction time for picture naming in a

second block of pictures would be expected to show a faster mean reaction time compared with the first block in which the pictures were named. Furthermore, the repetition effects would be expected to be greater for the weaker (L2) language compared to the repetition effects for the dominant L1. That is, in fact, what the data show in the Standard Picture Naming task. There was a small, but insignificant, repetition effect of approximately 30 ms for L1 items between the first and second blocks (non-switch items). English pictures demonstrated a much greater repetition effect for previously named items in the mixed block, which was expected based on previous research (e.g., Alvarez, Holcomb, & Grainger, 2003; Duyck et al., 2008; Hernandez, Bates, and Avila, 1996).

While no firm conclusions can be made at this point based simply on a comparison of initial single-language blocks and the critical mixed block of this task, it is possible that no significant L2 processing disadvantage exists in the mixed block. It is possible that the apparent inversion of “processing advantage” between L1 and L2 items in the mixed block can be explained by a combination of switch cost differences and differential effects of repetition. The role of repetition effects will be examined closely in the following chapters as a potential explanation for findings throughout the study.

RQ3. Does the L2 reaction time advantage in the mixed block carry over to subsequent single-language block L2 picture naming?

H3: Yes. Mean reaction times for final single-language blocks in the standard picture naming task (Experiment 1) will both be significantly faster than mean RTs for the initial single-language blocks due to practice effects. In addition to a general practice effect, the L2 advantage and L1 disadvantage will carry over to the final single-language blocks and

result in a greater overall RT decrease for L2 compared to L1 (as measured by initial single-language block 1 Mean RT – final single-language block Mean RT).

The pilot study investigated this question in terms of potential repetition advantage for the L2 during the 5-block picture naming series. Results from that study showed a significantly greater reaction time decrease (speed-up) for English items compared to Korean items when comparing the first and last single-language blocks. Based on these results, it was initially predicted that “the L2 advantage and L1 disadvantage found in the mixed block will carry over to the final single-language blocks.” However, based on the results discussed above, this data may be better examined without explicitly relying on the notion of an L2 disadvantage. It may be possible to account for the findings in the study based on increased repetition effects for L2 (compared to L1) items.

Based on results of past studies examining repetition effects (e.g., Bajo & Canas, 1989; Ferrand et al., 1998; Wheeldon & Monsell, 1992), faster reaction times were expected in the final block for pictures that had been named previously. In this task, “old” pictures for each language were named once in the initial single-language block and once in the mixed block. Therefore, repetition effects were expected in the final single language block and, based on past findings that L2 benefits more from repetition than L1, English items in the final single-language block were expected to show a greater decrease in reaction time. Critically, as repetition effects also positively affect L1, one would also expect a lower mean L1 reaction time when comparing the final block with the initial single language block. The data from this study support this prediction.

Comparing final block mean reaction times with initial single-language blocks, English items showed a decrease (speed-up) of approximately 150 ms. Korean items also benefited from repetition, but to a lesser extent (approximately 102 ms). Again, there is no evidence of an L1 disadvantage here; both languages appear to be positively affected by repetition effects, but L2 appears to be affected to a greater extent. As with RQ2, repetition effects appear to explain the results of this study without the need for a distinct L1 processing disadvantage (separate from the well-established, unequal effects of repetition effects on L1 and L2).

RQ4. If the L2 reaction time advantage in the mixed block carries over to subsequent single-language block L2 picture naming, does the advantage also exist for novel pictures (i.e., new pictures not presented in earlier blocks)?

H4: Yes. Just as the L2 reaction time advantage is hypothesized to carry over to the previously named pictures in the final single-language blocks, the same effect is expected for novel pictures named in the final blocks.

The addition of 27 novel pictures in each of the final single-language blocks is a design manipulation that is new to this study. To the author's knowledge, this design has not been implemented in past picture naming studies. Therefore, there was little in the extant literature on which to base a prediction on what the results would show. The hypothesis that both old and new pictures would benefit equally was based on the idea that pictures in the mixed block benefited from a language-specific processing advantage. Likewise, the processing "disadvantage" identified in the pilot study was expected to

carry over to the final language block, thereby uniformly affecting both new and old L1 pictures. This hypothesis was not supported by the data.

Reaction times for correctly named novel pictures (i.e. not previously named or seen by participants) shows a pattern similar to the overall initial and final block reaction time means, with Korean (1218 ms, $SD = 189.1$) pictures named significantly faster than English pictures (1363.8, $SD = 189.1$). In contrast to these results, there was no significant difference in reaction times between Korean ($M = 962.3$, $SD = 162.1$) and English pictures ($M = 982.4$, $SD = 157.7$) that had been previously seen and named during Block 1 and the Mixed Block.

Examination of data from the final single-language blocks reveals no L1 disadvantage compared to L2. Pictures that were not previously seen demonstrated the same pattern as initial single-language blocks (L1 faster than L2). The fact that no significant difference existed between old Korean and old English pictures can, once again, be explained by enhanced repetition effects for L1 items compared to L2. Also, once again, there is no need to posit an L1 processing disadvantage separate from the well-known effect of unequal repetition priming between first and second languages.

In sum, abandoning the notion of an L1 disadvantage created in the Mixed Block and carried over to the final single-language blocks, the results from this study can be explained by differential effects of repetition priming.

Turning to the final task, data from the Simon Task were used to examine correlations between bilingual language switch performance and general cognitive control. This task addresses the final research question:

RQ5. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual language switching tasks?

H5: A positive and significant correlation will exist between Simon Task performance and switching performance on the bilingual picture naming task.

Correlations were examined between participant Simon Task scores and mix and switch costs for both Korean and English stimuli. No significant correlations were found when calculating correlations between Simon Task scores and 1. Korean switch costs, 2. English switch costs, 3. Korean mix costs, and 4. English mix costs.

Based on previous language processing and aptitude studies detailed in the literature review, a link is thought to exist between general cognitive control ability and language control required in bilingual processing tasks. If this were the case, one might expect to see significant correlations between performance on the Simon Task and mix and switch costs in the Standard Picture Naming Task. More specifically, individuals with higher mean Simon Effect scores, which reflect a relatively poorer ability to overcome prepotent responses, might be expected to demonstrate greater switch costs in the Standard Picture Naming Tasks. Therefore, a direct relationship between non-linguistic, more general cognitive control ability (as measured by the Simon Task) would appear as a positive correlation with language switch effects. That is, individuals who demonstrate relatively greater difficulty overcoming prepotent responses in the Simon Task might also be expected to demonstrate relatively greater difficulty overcoming the prepotent tendency to respond in the dominant L1 when forced to switch to a less dominant L2. However, no significant correlations were found between Simon Task

performance and switch costs in the picture naming task. In fact, no correlations neared significance for any of the four correlations conducted. The largest effect, and closest to reaching (but still far from) significance, was the correlation between Simon Task scores and Mixed Block Korean mix costs (.217, $p = .184$). As discussed in the Results Section for this task, the lack of significant correlation was not totally unexpected due to a sample size smaller than that normally used for correlation analyses.

Summarizing the results from Experiment 1, data from the Standard Picture Naming task demonstrated the following:

1. Asymmetric switch costs, with switches to the first language taking longer than switches to the second language. This result was expected.
2. Second language processing advantage in the critical Mixed Block. This result was expected.
3. No clear L2 processing disadvantage in the critical Mixed Block that cannot be explained by differential effects of repetition priming. This result was not expected, but is in line with findings from past repetition priming research.
4. No significant reaction time difference between final block English and Korean items that had been previously named in earlier blocks. Differential effects of repetition priming account for this finding without the need for a separate, independent L1 disadvantage carried over from the mixed block (i.e., the initial predication, which was not supported by the data).
5. A significant difference between novel English and Korean pictures in the final picture naming blocks, with Korean pictures named faster on average than novel English pictures. Combined with Point 4 above, this result adds further evidence

to differential effects of repetition priming between first and second languages.

This finding also contradicts the notion that inhibitory control-related effects from the Mixed Block affect the entire L1 and carry over to the final blocks.

6. No direct relationship between non-linguistic cognitive control ability, as measured by the Simon Task, and language switching ability as operationalized as mix and switch effects in the Standard Picture Naming Tasks.

These findings will be discussed in more detail in Chapter 10, the General Discussion. In the next section, Experiment 2 will be detailed and discussed.

8 Go No-Go Picture Naming Task (Experiment 2)

8.1 Go No-Go Task Overview

Experiment 2 utilizes a modified picture naming task to determine if an L2 advantage and L1 disadvantage exist in mixed conditions in which verbal responses are only required for one language. Unlike the 5-block design used in Experiments 1, Experiment 2 contains two mixed blocks of pictures. The critical modification in this picture naming task is the inclusion of a Go No-Go manipulation, which require participants to verbally name the pictures of only one target language per block (with no verbal response to non-target language pictures). Data from this task was used in an effort to determine whether the L2 advantage commonly reported in mixed language tasks is dissociable from the requirement to verbally name pictures in both L1 and L2. One potential explanation for L2 advantage in mixed language conditions is the tendency to bias selection toward the more difficult language (L2) when naming in both L1 and L2 is required. If that is the case, data from the mixed block of this task should demonstrate no L2 advantage and no L1 disadvantage because only one language is required per block. The directions for this task emphasize that only one language is required per mixed block, and the other language would not be used during the entirety of the naming block despite the appearance of both yellow (L1/ Korean) and blue (L2/ English) pictures.

The design of this task also allowed for the examination of switch costs. Asymmetric switch costs (i.e., faster reaction times for switching to L1 compared with switches to L2) have been reported for mixed conditions in which stimuli from both languages are named. However, it is unclear whether this effect is due to the need to articulate verbal responses in both languages, or if simply the presence of two competing

languages is sufficient to create asymmetric switch costs. Switch costs in Block 3 of this task, as measured by reaction times for correctly naming pictures that follow non-verbalized stimuli (the non-target language for that block) were compared with switch costs into target language responses in Block 4. In this way, switch costs into the L1 and L2 can be measured and compared for asymmetry.

The final goal of this task was to replicate the differential replication effects between the first and second languages as found in Experiment 1.

The research questions addressed by Experiment 2 are as follows:

RQ1. Does the L2 reaction time advantage and L1 disadvantage persist in a Go-No Go variant of the picture naming task in which participants only verbally respond to one of the two languages?

RQ2. Do switch costs exist in a Go-No Go variant of the picture naming task in which participants only respond to one of the two languages?

RQ3. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual?

Method

8.1.1 Participants

A total of 30 native speakers of Korean who are proficient in English were recruited for this study. Participants were recruited from the University of Maryland campus community by printed and electronic advertisement as well as from the Penn State University campus community through a nearby Korean church. To avoid potential age-related influences on picture naming performance, only participants between the ages of 18 and 45 were recruited. The mean age of participants in Experiment 2 was 32 years old ($SD = 4.7$, range 22-39 years old). Time in the United States ranged from 1 to 13 years ($M = 4.7$ years, $SD = 3.5$), and the average age at which participants began English instruction in Korea was 11.5 years ($SD = 1.6$). No participant lived in a predominantly English-speaking country before the age of 15. Participants were paid \$15 for participation in one 1-hour, twenty minute testing session. Individuals who participated in Experiment 1 were not eligible for this experiment.

8.1.2 Design

The Go No-Go picture naming task is composed of four (4) blocks of stimulus pictures (see figure 11, below). The first two blocks are single language blocks in which 54 pictures are presented on the same color background, either blue or yellow, depending on the language order. In the first block, half of the participants were presented with blue pictures to be named in English. The other half of the participants began the task in Korean, and were presented with yellow pictures.

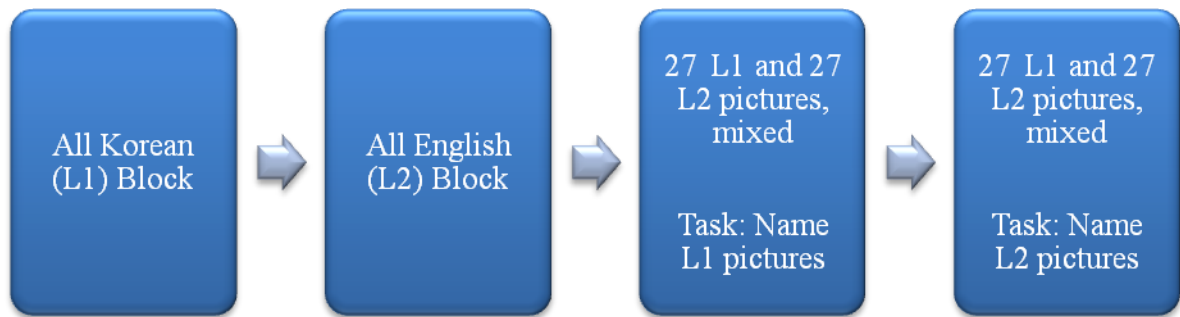


Figure 11. Go No-Go Picture Naming task design

The third and fourth blocks were mixed language blocks, in which 27 L1 pictures (Korean/ yellow) were mixed with 27 L2 pictures (English/ blue) and presented in a fixed order. In the first mixed block, participants were instructed to name pictures for only one language and provide no response for the alternate color/language (counterbalanced). For example, if instructed to name only pictures with a yellow background in Korean, the participants were to say the Korean names of the yellow-framed items into the microphone. For pictures with blue backgrounds, the participants were told to not respond, and that the stimulus slides would time out and move to the next item after 4 seconds. The non-target language (English, in this example) was *never produced* during the entire block.

The critical blocks (1 Korean-only response and 1 English-only response block) were preceded by one pure L1 block and one pure L2 block (counterbalanced) in which participants simply named pictures using the correct language for each color.

It should be noted that the Go No-Go decision in this task (i.e., the decision to name the picture or not) is signaled by the background color of the screen and not by an auditory tone as often signaled in traditional Stop and Go Tasks (e.g., Philipp, Jolicoeur, Falkenstein, & Koch, 2007; Schuch & Koch, 2003). Also, whereas the time between

stimulus onset is often manipulated in traditional Stop and Go Tasks, the color cue in this task appears immediately upon presentation of the picture stimuli.

8.1.3 Materials

With the exception of 2 replacement items, the same 108 pictures used in Experiment 1 were used in Experiment 2. The pictures were ordered according to frequency and split into four separate lists, with each list containing 27 pictures. The mean syllable length for items in this task was approximately 1.5, and the mean log frequency was approximately 3.0 based on the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993). Two of the four lists were presented on a yellow background, indicating that the pictures were to be named in Korean. Pictures from the remaining two lists were presented on a blue background, indicating that the pictures were to be named in English. One set of Korean pictures was paired with English pictures for each experimental block, and the pictures were presented in a fixed order to enable the measurement of potential mix and switch effects related to the naming task.

8.1.4. Scoring and Analysis

High and low cut-off points for reaction times were first set at 300ms and 4000ms. Responses with reaction times falling outside of this range were discarded. The participant mean and standard deviations were then computed and values +/- 3 SDs from the mean were also removed. Voice responses were then coded according to the following scoring system:

1. Correct

2. Liberal correct (e.g., “dog” for the target “wolf”)
3. Error (no response, or wrong response in correct language)
4. Language error (correct or incorrect response in wrong language)
5. Technical error (equipment problem) or extraneous noise (causing early RT capture)

Answers judged as “liberal correct” were scored as correct if both responses (e.g., the single-language block and the mixed block) were the same. For example, the response “dog” was scored as a correct response for the stimulus “wolf” due to ambiguity in the line drawing picture.

Missing data resulting from technical errors (e.g., no voice capture despite a voiced response), extraneous noise, lack of response, and incorrect responses were removed from analysis. Data preparation resulted in removal of approximately 8.5% of data from this task.

Reaction times for correctly named target language pictures appearing after non-target language pictures (“switch trials”) were compared with reaction times for correctly named target language pictures following other target language pictures (“non-switch”). Reaction time comparisons were within subject, and within the same block (“switch vs. non-switch” items within the same block). This analysis was conducted two times (once for each target language block). Switch costs were examined by subtracting non-switch trial RTs from switch trial RTs within the mixed language block. A repeated measures ANOVA was used to compare mean L1 to L2 switch reaction times with L2 to L1 switch times. Finally, correlations were examined between Go No-Go picture naming performance and Simon Task scores

8.1.5 Procedure

After providing informed consent, participants completed a Demographic Information and Language Use survey (Appendix I). This survey elicited information about participant language study history as well as current use of L1 (Korean), L2 (English), and other languages known.

Participants were tested individually in a quiet room on a Dell laptop computer with 15” monitor. The picture naming task was presented first using E-Prime 2.0 (PST, Pittsburgh, PA) and, in addition to reaction time data collected in E-Prime, voice responses were recorded with a Sony digital recorder for later analysis. Participants spoke into an Audio-Technica AT20 microphone secured in a microphone stand and positioned in front of their mouth in a manner that was comfortable and did not obstruct the participants’ view of the computer screen. After the Go No-Go picture naming task, participants completed two receptive processing tasks, a lexical decision task and a semantic categorization task. These tasks are detailed in Chapter 9.

After completion of all three bilingual language processing tasks, participants completed a computer-delivered Simon Task, presented using E-Prime 2.0 (PST, Pittsburgh, PA), and a Lexical Robustness task, which was administered verbally by the researcher. These tasks were followed by a short exit interview in which participants were asked about any strategies used to complete the tasks in order to identify any unintended influences on their performance. Once all the tasks were complete, the participants were debriefed, paid \$15, and thanked for their participation. The participants then had the opportunity to ask questions about the study before they left the testing station.

8.1.6 Results

Mean accuracy for this task was approximately 96%. One participant was dropped due to low accuracy (failure to follow instructions in the critical mixed block), leaving a total of 29 participants who completed this task. Mean reaction times (with Standard Deviations) for each block are presented below in Table 7.

Table 7. Go No-Go Picture Naming Task mean reaction times by block

All English Block 1	All Korean Block 1	Mixed Block English		Mixed Block Korean	
$M = 1372.6$ (209.1)	$M = 1177.9$ (244.7)	$M = 1121.7$ (143.5)		$M = 1036.0$ (191.5)	
		NonSW	SW	NonSW	SW
		1112.0	1135.4	1040.7	1019.5

Correctly named pictures in the initial single language blocks are similar to Experiment 1 in that Korean pictures ($M = 1177.9$, $SD = 244.7$) were named faster than English pictures ($M = 1372.6$, $SD = 209.1$). As was the case in Experiment 1, this difference is significant ($F(1,28) = 36.62$, $p < .001$; $F(1, 107) = 84.56$, $p < .001$) based on a Repeated Measures ANOVA. Unlike Experiment 1, the mean reaction time for Korean pictures remained faster than English pictures in the critical mixed block. The mean RT for Korean pictures in the Mixed Block was 1036.0 ms ($SD = 191.5$) and the mean RT for English pictures was 1121.7 ms ($SD = 143.5$). This difference is also significant ($F(1,28) = 10.70$, $p < .001$; $F(1,107) = 9.01$, $p < .05$). Figure 12 provides an illustration of mean reaction times by block and language.

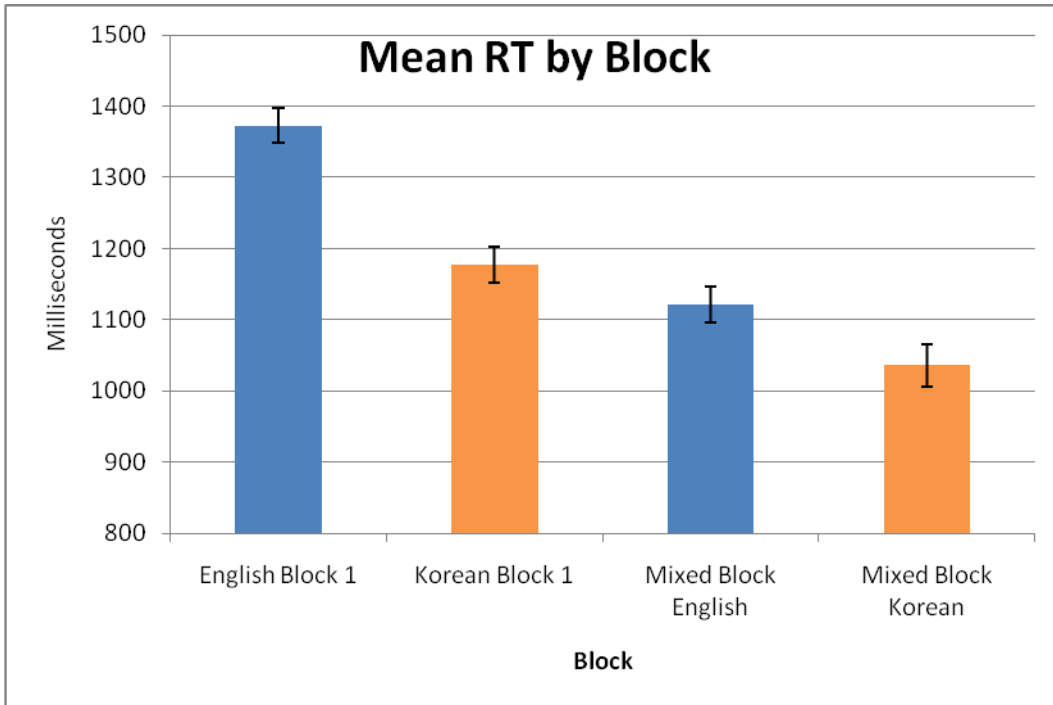


Figure 12. Go No-Go Task mean reaction times by block

Despite an overall slower mean reaction time for English pictures in the mixed block, English picture naming performance demonstrated a larger decrease in reaction time from Block 1 and a larger mix effect compared to Korean. In this task, both Korean and English picture naming performance benefited from repetition. The mean mix cost (Mixed Block non-switch mean minus Block 1 mean for each language) for Korean was -137.2 ms ($SD = 205.2$) and the mean mix cost for English was -260.6 ms ($SD = 167.4$). Repeated Measures ANOVA shows this difference to be significant ($F(1,28) = 18.4$, $p < .001$; $F(1, 107) = 32.16$, $p < .001$). A 2 (Language) x 2 (Block) Repeated Measures ANOVA showed a significant main effect of Language ($F(1,28) = 31.80$, $p < .001$; $F(1,107) = 41.76$, $p < .001$) and Block ($F(1,28) = 39.47$, $p < .001$; $F(1,107) = 144.00$, $p < .001$) and a significant interaction between Language and Block ($F(1,28) = 18.42$, $p < .001$).

< .001; $F_2(1,107) = 32.17, p < .001$). Average Korean and English mix costs are presented in Table 8.

Table 8. Go No-Go mean English and Korean mix costs

English Mix Costs	Korean Mix Costs
-260.6 ms ($SD = 167.4$)	-137.2 ms ($SD = 205.2$)

The following chart displays the mean reaction times for different trial types in the critical mixed blocks. Note that, unlike Mix Block results from the Standard Picture Naming Task in Experiment 1, there is no inversion of processing advantage (i.e. faster scores) between Korean and English. In all cases, mean reaction times for Korean items were faster than mean reaction times for English items.

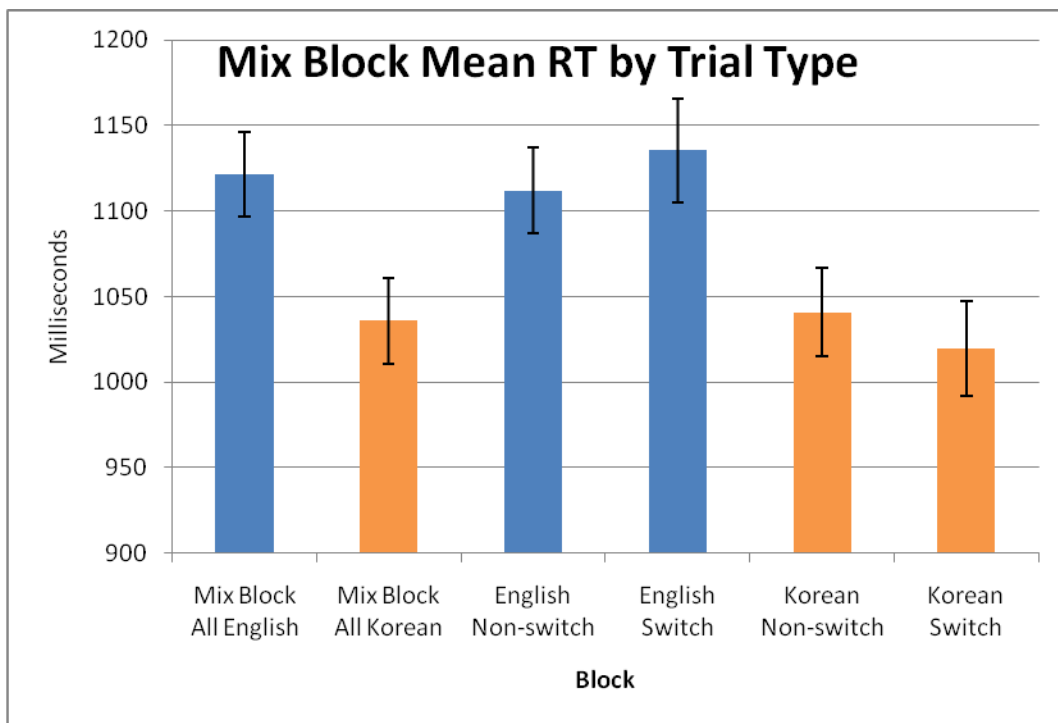


Figure 13. Mix block reaction times by trial type

Although participants only responded verbally to pictures from one language in each of the final blocks, the presented stimuli included both Korean (yellow) and English (blue) pictures. Therefore, switch effects (from one language to another) were still possible. The mean switch costs in Experiment 2 were 23.4 ms ($SD = 142.2$) for switches into English and -21.1 ms, ($SD = 130.5$) for switches into Korean. Mean switch costs are presented in Table 9.

Table 9. Go No-Go Task switch costs

English switch costs	Korean switch costs
$M = 23.4$ ms, $SD = 142.2$	$M = -21.1$ ms, $SD = 130.5$

(*difference not significant)

A 2 x 2 Repeated Measures ANOVA with the factors Language (English and Korean) and Trial Type (Switch and Non-switch) was conducted to examine the performance difference. The main effect of Language was significant ($F(1,28) = 13.76$, $p < .001$; $F(1, 107) = 11.25$, $p < .001$), but the main effect of Trial Type ($F(1,28) < 1$, n.s.; $F(1, 107) = 1.06$, n.s.) and interaction effect of Language and Trial Type were not significant ($F(1,28) = 1.51$, n.s.; $F(1,107) = 1.40$, n.s.). Figure 14 illustrates Go No-Go switch cost results.

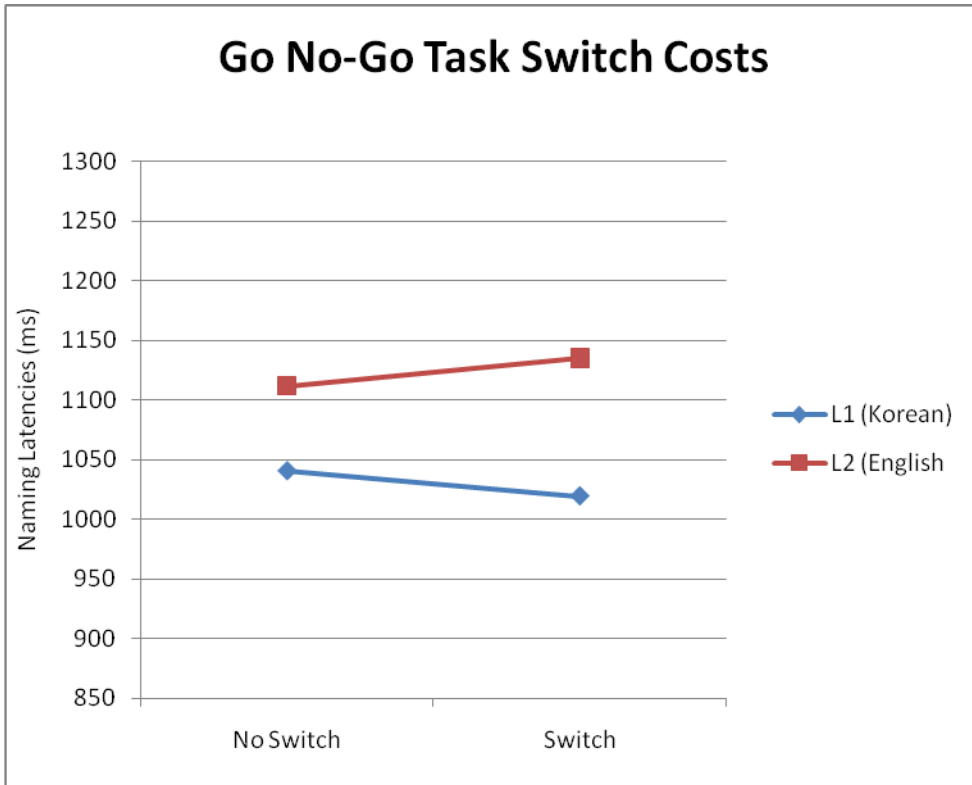


Figure 14. Go No-Go Task switch costs by language and trial type

8.2 Simon Task

As in Experiment 1, the Simon Task was used as a measure of general cognitive control in Experiment 2. The task and scoring procedures are as presented in section 7.4.

8.2.1 Results

As in Experiment 1, Experiment 2 participants reported little difficulty with the Simon Task. The mean accuracy for the 30 participants tested was nearly 98% (range 94-100%), and the mean Simon Effect was 34 ms ($SD = 25.1$). Although the mean Simon effect reflected generally slower responses for incongruent responses compared to congruent, the actual effect varied greatly between participants. The greatest slowdown observed was approximately 84 ms, but several scores reflected little to no change between conditions. Two participants of the thirty tested demonstrated slightly faster

reaction times for incongruent stimuli, but the effect was relatively small in both cases (range = -12 to -15 ms).

Correlations were examined between participant Simon Task scores and mix and switch costs for both Korean and English stimuli. No significant correlations were found when calculating correlations between Simon Task scores and 1. Korean switch costs, 2. English switch costs, 3. Korean mix costs, and 4. English mix costs.

As previously discussed, a link may exist between general cognitive control ability and language control required in bilingual processing tasks. Therefore, one might expect to see significant correlations between performance on the Simon Task and mix and switch costs in the Go No-Go task. More specifically, individuals with higher mean Simon Effect scores, which reflect a relatively poorer ability to overcome prepotent responses, might be expected to demonstrate greater switch costs in Go No-Go task. Therefore, a direct relationship between non-linguistic, more general cognitive control ability (as measured by the Simon Task) would appear as a positive correlation with language switch effects. However, no significant correlations were found between Simon Task performance and switch costs in the Go No-Go task. In fact, no correlations neared significance for any of the four correlations run. Based on the relatively small sample size, however, these results were not unexpected. The existence of a stable Simon Effect (+34 ms) signals that the measure worked as intended, and might serve as an appropriate measure of cognitive control in future, larger-scale studies.

8.3 Lexical Robustness Measure

The verbal proficiency measure included in this study was adapted from Schwieter & Sunderman (2008) and was designed to provide a measure of participants' vocabulary knowledge. This measure, based on the experimental procedures of Gollan, Montoya, and Werner (2002), is described as a method of operationalizing the "robustness of the L2 lexicon" (Schwieter & Sunderman, p. 223). Costa et al. (2006) also refer to "lexical robustness" and defined it as the familiarity with and frequency of access that leads to greater automaticity of lexical retrieval. The task was verbally administered to the participant by the researcher, who provided a category for which the participant provided (orally) as many examples as possible in one minute. There were a total of ten categories, and the total score was calculated by adding the number of all correct responses to determine an overall score. Duplicate answers and answers outside of the required category were not counted toward the final score.

The verbal fluency measure was included in Experiment 2 for two reasons. First, the number of category-specific items an individual can produce within one minute could be used as additional information to better estimate participants' vocabulary knowledge. While this measure does not provide a full measure of a participant's global L2 proficiency, it does produce useful information that, when combined with data from the language history questionnaire, provides a reasonable estimation of L2 vocabulary knowledge in a short period of time. Second, Schweiter and Sunderman (2008) used this measure to investigate where along the continuum of lexical robustness participants moved from reliance on inhibitory control to more language-specific processing. As the research questions of the current study overlap significantly with the core questions in Schweiter and Sunderman's (2008) investigation into bilingual language selection, the

use of the same proficiency measure for a different population may produce useful data for future studies on this issue.

A total of 30 participants completed this task, and the mean final score was 133 ($SD = 22.8$). Lexical Robustness scores varied greatly between the participants, with a minimum score of 95 and a maximum score of 195. The variation in scores was similar to that in Experiment 1. Once again, there was no apparent relationship between Lexical Robustness scores and education level (e.g., undergraduate students vs. post-doctorate fellows), nor was there a significant relationship between Lexical Robustness scores and time in the United States. The average age at which participants began learning English in Korea was approximately 11.5 years ($SD = 1.56$). The correlation between starting age for English language education (in Korea) and Lexical Robustness scores was $-.216$ (n.s). While the correlation between English start age and Lexical Robustness score did not reach significance in this study, the final correlation including all 70 participants did ($-.401, p < .001$). This will be discussed in more detail with results from Experiment 3.

8.4 Discussion

The results will be discussed in relation to this experiment's three research questions and hypotheses.

RQ1. Does the L2 reaction time advantage and L1 disadvantage persist in a Go-No Go variant of the picture naming task in which participants only verbally respond to one of the two languages?

Hypothesis 1: Yes, the L2 reaction time advantage and L1 reaction time disadvantage found in the pilot test will persist in the Go No-Go variant of the picture naming task in which participants only verbally respond to one of two languages. Despite only naming

one language in each mixed block, the mixed language environment will positively affect English picture naming and negatively affect Korean picture naming.

As was the case in both the pilot study and Experiment 1, correctly named pictures in the initial single language blocks demonstrated a significantly faster mean RT for Korean pictures ($M = 1177.9$, $SD = 244.7$) compared to English pictures ($M = 1372.6$, $SD = 209.1$). However, unlike the pilot test and Experiment 1, the mean reaction time for Korean pictures remained significantly faster than the mean reaction time for English pictures when comparing the critical mixed blocks (Korean $M = 1036$ ms; English $M = 1121.7$ ms). Data from the Go No-Go task demonstrated no inversion of reaction time scores, with Korean pictures named faster than English pictures in both the single language blocks as well as the critical mixed blocks. Based on these results, no apparent L1 disadvantage existed for picture naming in mixed language conditions in which only one language was named out loud.

In this task, both Korean and English picture naming performance benefited from the mixed condition. The mean mix cost for Korean was -137.2 ms ($SD = 205.2$) and the mean mix cost for English was -260.6 ms ($SD = 167.4$). A closer look at the data reveals that, despite a slower mean RT for English pictures in the mixed block, English picture naming performance demonstrated a significantly larger decrease in RT from Block 1 and a larger mix effect compared to Korean.

While no dramatic processing disadvantage appears to exist for L1 in the mixed condition for this task, the relatively greater mean RT decrease for L2 items must still be explained. Once again, the unequal effects of repetition priming for low frequency and second language items (e.g., Hernandez & Reyes, 2002) seem sufficient to explain these

findings. That is, the smaller decrease in Korean mean reaction time between the initial and mixed block need not imply a processing disadvantage for naming Korean items in a mixed language environment. Korean items do, in fact, demonstrate a significant speed up (decrease in RT) from the first block to the second. Based on this finding, there is little here to suggest a distinct L2 processing disadvantage separate from the already-established finding that L1 (or dominant language) processing benefits less than L2 (less dominant) processing from repetition priming. Therefore, once again, results from this data set support the role and unequal effects of repetition priming, but do not represent the need for a separate L1 disadvantage resulting from a mixed language environment.

RQ2. Do switch costs exist in a Go-No Go variant of the picture naming task in which participants only respond to one of the two languages?

H2. Yes. Despite only producing a response to the language designated as the target language for the block, activation of non-target language lexical items will still create a switch cost when switching back to produce the targeted language (even though the non-target language was never vocalized).

Past switch studies have demonstrated consistent asymmetric switch costs for unbalanced bilinguals performing picture naming tasks (e.g., Costa & Santesteban, 2004; Costa et al., 2006; Meuter & Allport, 1999; Schwieter & Sunderman, 2008). Results from the pilot study (and Experiment 1) provide further support for expected switch cost asymmetry for participants in bilingual picture naming tasks. Based on consistent asymmetric switch cost for unbalanced bilinguals in the literature and similar results from a pilot study targeting the same population as the current study, it was expected that

participants in the current study would also demonstrate asymmetric switch costs during this bilingual picture naming task, despite the need to verbally respond with only one language in the critical mixed block.

Data from the study do not support this hypothesis. While participants only responded verbally to pictures from one language in each of the final blocks, the presented stimuli included both Korean (yellow) and English (blue) pictures. Participants were expected to demonstrate a switch cost when switching languages and, possibly, asymmetric switch costs in line with those demonstrated in the Standard Picture Naming Task. Neither of these predictions was supported by the data.

The mean switch cost from English to Korean was -21.1ms ($SD = 130.5$), and the mean switch cost from English to Korean was 23.4ms ($SD = 142.2$). A 2×2 ANOVA revealed a non-significant interaction between language and trial type, demonstrating no significant differences between how language switching in this task affected Korean and English in terms of switch costs. Not only was no significant asymmetric switch cost found, the slight difference in switch costs that did appear was in the opposite direction, with switches to Korean slightly faster than non-switch trials.

To the author's knowledge, no previous study has included a Go No-Go picture naming task with the same design as the Experiment 2 task. The hypothesis developed for this research question was based on standard picture naming task results, where both language responses were articulated and switch cost asymmetry has been shown to exist, as well as the general task switching literature (e.g., Monsell, 2003). However, no asymmetric switch costs were found.

The lack of asymmetric switch costs can be explained by the need to only name pictures for one language per block. In this case, it is possible that this condition may have been treated much like a single-language block by the participants, rather than a mixed block. While this possibility was considered, the fact that participants previously named all pictures, both for the response language and the non-response language, in the first and second blocks created the possibility that non-response language picture names would be activated during the mixed block as well. During the exit interview, participants were asked how they approached this task, and if they recognized the items for the Mixed Block non-response language as previously named pictures. Participants stated that they did, and several participants reported silently naming non-target pictures in the non-response language. Based on this, it seems possible that activation of both languages during the task might create asymmetric switch costs similar to those found in standard picture naming tasks. As significant switch costs were not observed in this task, it appears that verbal responses for the non-target language, or at least the requirement for verbal responses, played a role in the absence of switch costs. This is contrary to initial predictions.

The lack of L2 reaction time advantage in mixed blocks for the Go No-Go tasks is in contrast to results from both the pilot test and the Standard Picture Naming Task in Experiment 1. Differences in switch cost results between the Standard Picture Naming Task and the Go No-Go task focus attention on the key difference between the two tasks; the fact that only one response language per block is required for the Go No-Go task appears to nullify the L2 Mixed Block advantage found in Experiment 1.

As previously discussed, one potential explanation for L2 advantage in mixed language conditions is the tendency to bias selection toward the more difficult language (L2) when naming in both L1 and L2 is required. If that were the case, data from the mixed block of this task should demonstrate no L2 advantage and no L1 disadvantage because only one language was required per block. Data from this task support this account.

Results from this task are also in line with Levy et al.'s (2007) hypothesis that isolates the role of inhibition to resolving competition between phonological labels during production. Although Levy et al. (2007) focused mainly on first language attrition (i.e. retrieval induced forgetting), the notion of a phonological-inhibition effect might also explain the lack of significant asymmetric switch costs in the Go No-Go task. By this account, while the production requirement for both languages would create the phonological-inhibition effect in Experiment 1, the requirement to name only one language at a time in Experiment 2 would avoid this effect. Data from this task also support this account.

RQ3. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual language switching tasks?

H3: A positive and significant correlation will exist between Simon Task performance and switching performance on the Go No-Go bilingual picture naming task.

Correlations were examined between participant Simon Task scores and switch and mix costs for both Korean and English stimuli. No significant correlations were found when calculating correlations between Simon Task scores and mix and switch

costs for either language. English mix costs and Korean mix costs correlated at .671 ($p < .001$), but no correlation involving Simon scores neared significance.

As was detailed in the results section of Experiment 1, it is believed that a link may exist between general cognitive control ability and language control required in bilingual processing tasks. If this were the case, one might expect to see significant correlations between performance on the Simon Task and mix and switch costs in bilingual picture naming task. More specifically, individuals with higher mean Simon Effect scores, which reflect a relatively poorer ability to overcome prepotent responses, might be expected to demonstrate greater switch costs in the bilingual processing tasks. However, no significant correlations were found between Simon Task performance and switch costs in the Go No-Go picture naming task. In fact, no correlations neared significance for any of the targeted correlations in Experiment 1 or 2.

9 Receptive Tasks (Experiment 3)

The two main tasks for Experiment 3— Lexical Decision and Semantic Categorization—were administered to all participants in Experiments 1 and 2 as presented in the General Procedure sections of each experiment. Details of the Lexical Decision and Semantic Categorizations tasks are presented below. The research questions addressed by Experiment 3 include the following:

RQ1. Does language switch cost asymmetry exist in Lexical Decision and Semantic Categorization tasks?

RQ2. Does the L2 RT advantage and L1 RT disadvantage carry over to subsequent single-language blocks in the Lexical Decision and Semantic Categorization Tasks?

RQ3. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual language switching tasks?

The Lexical Decision Task will be discussed first, followed by the Semantic Categorization Task and overall results for the Simon task and lexical fluency measure.

9.1 Lexical Decision Task

The purpose of the Lexical Decision task in this experiment was to determine the extent to which mix and switch effects commonly found in production tasks extend to receptive tasks. Specific foci include the existence of asymmetric switch costs and potential L2 advantage in the mixed language condition as well as the possibility that the L2 advantage extends to later single language lexical decision blocks.

Method

9.1.1 Participants

The mean age for the 70 participants in this study was 31.6 years old ($SD = 5.9$; range 20-43). Participants included more males (40) than females (30), and education levels of the participants were as follows: 10 undergraduate students, 47 graduate students, and 13 post doctorate researchers/ visiting scholars. The average number of years spent in the United States varied, with an average of 6.1 ($SD = 3.91$) and a range of 1-16 years. Participant recruitment and payment procedures are as reported in the earlier studies.

9.1.2 Design

The lexical decision task in Experiment 3 follows the 5-block design utilized in earlier tasks. In Block 1, participants were presented with a list of L1 words and L1 nonwords and were instructed to decide if the letter string was a word in the target language for the block (Korean in this example, although the actual presentation order was counterbalanced across participants). Participants were asked to make the same decision in Block 2 for L2 words and nonwords. In the critical mixed condition (Block 3), words and nonwords from both languages were presented in a fixed order to enable a comparison of switch and non-switch trials in addition to measuring general language mixing effects. Each word in the Mixed Block could occur in four possible contexts: 1) after a word from the same language, 2) after a nonword from the same language, 3) after a word from the other language, and 4) after a nonword from the other language.

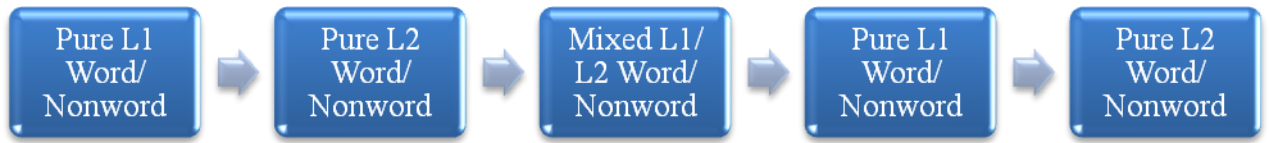


Figure 15. Lexical Decision Task 5-block design

9.1.3 Materials

A total of 256 stimuli, 128 words and 128 nonwords, were prepared for this task. The stimuli list included 64 Korean words and 64 English words (all concrete nouns) matched for frequency and syllable count, and 64 Korean nonwords and 64 English nonwords matched for syllable length (see Appendix C and D). Nonwords in both languages were phonetically legal, and Korean nonwords were checked by three native speakers to ensure that the words did not exist in standard Korean or a commonly known dialect.

9.1.4. Scoring and Analysis

A low cut-off point for reaction times was first set at 300 ms. Responses with reaction times falling below 300 ms were discarded. (Due to the programmed cutoff at 3000 ms, no upper limit reaction time was set for data analyses.) The participant mean and standard deviations were then computed and values ± 3 SDs from the mean were also removed. Removal of incorrect responses and scores above and below the cutoffs accounted for approximately 7% of the data.

A repeated-measures ANOVA was used to compare lexical decision reaction times between L1 and L2 blocks, first single-language blocks and final single-language blocks, as well as lexical decision performance in the mixed condition. Switch costs were

measured and analyzed for switch asymmetry in the critical mixed language block. As with the picture naming tasks in Experiments 1 and 2, potential carry-over effects from any mixed block L2 advantage were also examined in the final two single-language blocks.

9.1.5 Procedure

As the tasks for Experiment 3 were administered during Experiment 1 and 2 testing sessions, the general procedure follows those of the earlier experiments. For clarification purposes, it should be noted that the task presentation order was fixed for all three experiments. The task order was as follows: Picture Naming Task (Standard or Go No-Go, depending on the Experiment), Semantic Categorization Task, Demographic Questionnaire, Lexical Decision Task, and, lastly, the Lexical Robustness Task.

The Lexical Decision task was presented using E-Prime 2.0 (PST, Pittsburgh, PA). Prior to the start of the task, participants were told that they would see a string of letters and that they should decide as quickly and accurately as possible whether the string is a word in either of their two languages. They were instructed to press the M key (marked YES) if the string formed a word in either of their languages and the X key (marked NO) if the string did not form a word in either language. They were instructed to keep their fingers positioned on the appropriate keys throughout the duration of the experiment so that they could respond as accurately as possible. The critical lexical decision blocks were preceded by a practice block in order to familiarize the participants with the task. The practice block could be repeated as many times as required for the participants to feel comfortable with the task and appropriate response mapping on the keyboard (no

participant repeated the practice block). Stimuli were presented in the center of the computer screen in black 20-point Times New Roman font on a white background. Stimuli remained on the screen until either a response was detected or 3000 ms had elapsed. If no response was detected after 3000 ms, the item timed out and the next stimulus item was presented.

9.1.6 Results

Overall, mean accuracy for the Lexical Decision task was approximately 95%. Data from three participants revealed very low mean accuracy in at least one of the five blocks (< 60% mean accuracy for at least one block). These three participants were dropped from analyses completely. In addition, one participant was unable to complete the whole testing session. Removal of three participants for low accuracy and one participant who did not complete the task resulted in a total N size of 66 for the Lexical Decision Task.

Mean reaction times for each of the five blocks are presented below in Table 10.

Table 10. Lexical Decision Task mean reaction times

Block 1 Korean	Block 1 English	Mix Block Korean	Mix Block English	Block 2 Korean	Block 2 English
<i>M</i> = 593.7(87.3)	<i>M</i> = 807.0(158.1)	<i>M</i> = 589.6(76.3)	<i>M</i> = 686.8(96.7)	<i>M</i> = 542.6(69.3)	<i>M</i> = 638.7(95.7)

The mean reaction time for correct responses in the first English block was 807.0 ms (*SD* = 158.1) and the mean reaction time for the first Korean block was 593.7 ms (*SD* = 87.3). A repeated measures ANOVA showed this difference to be significant ($F(1, 65)$

= 166.4, $p < .001$; $F_2(1, 63) = 100.1, p < .001$). Examination of Lexical Decision task data reveals consistently faster mean Korean responses compared to English responses across all blocks. That is, as was the case with the Go No-Go task, no outright processing advantage was apparent for English in any block. To allow for a visual comparison, reaction times for each block are presented below in Figure 16.

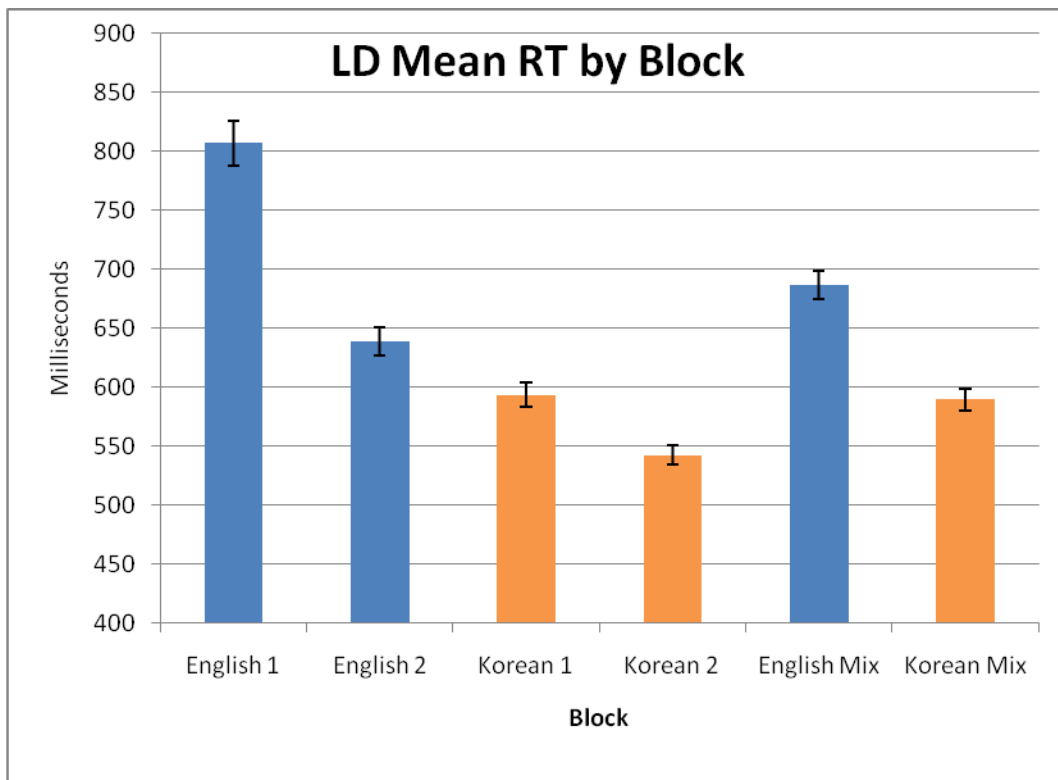


Figure 16. Lexical Decision Task mean reaction times by block

Within the critical Mixed Block, results from the Lexical Decision task show a pattern similar to that found in the Go No-Go task and Semantic Categorization Tasks (see Table 11). That is, mean reaction times for Korean items are faster than mean reaction times for English items. Furthermore, results from this task show slower reaction times for switch items compared to non-switch items in the mixed language environment.

Table 11. Lexical Decision mixed block mean RTs by language and trial type

Mix Block Korean	Mix Block English	Mix BK KOR Nonswitch	Mix BK KOR Switch	Mix BK ENG Nonswitch	Mix BK ENG Switch
589.6(76.3)	686.8(96.7)	580.3(71.3)	598.9(86.0)	668.3(92.1)	704.0(107.2)

Mix costs were calculated by subtracting the Mean RT for the initial single language block from the Mean RT of non-switch Mixed Block pictures for both Korean and English (see Table 12. below).

Table 12. Lexical Decision Task mix costs by language

English Mix Costs	Korean Mix Costs
$M = -138.8, SD = 99.1$	$M = -13.3 \text{ ms}, SD = 62.5$

Analysis of Variance revealed a significant difference ($F(1,65) = 78.52, p < .001$; $F(1, 63) = 77.60, p < .001$) between Korean ($M = 13.3\text{ms}, SD = 62.5$) and English ($M = -138.8, SD = 99.1$) mix costs. Correctly named Korean mixed block pictures ($M = 589.6 \text{ ms}, SD = 76.3$) showed no significant increase or decrease in reaction time ($F(1,65) = .303, \text{ n.s.}; F(1,63) = .388, \text{ n.s.}$) compared to the initial all-Korean block reaction times ($M = 593.7 \text{ ms}, SD = 87.3$). However, English mixed block reaction times were markedly faster than the initial all-English block RTs. The difference between the all-English Block 1 mean reaction time ($M = 807.0 \text{ ms}, SD = 158.1$) and the mix block English non-switch mean reaction time ($M = 686.8 \text{ ms}, SD = 96.7$) was significant ($F(1,65) = 65.00, p < .001$; $F(1,63) = 93.23, p < .001$) and demonstrates a robust

processing advantage for correctly named English pictures in the mixed language condition.

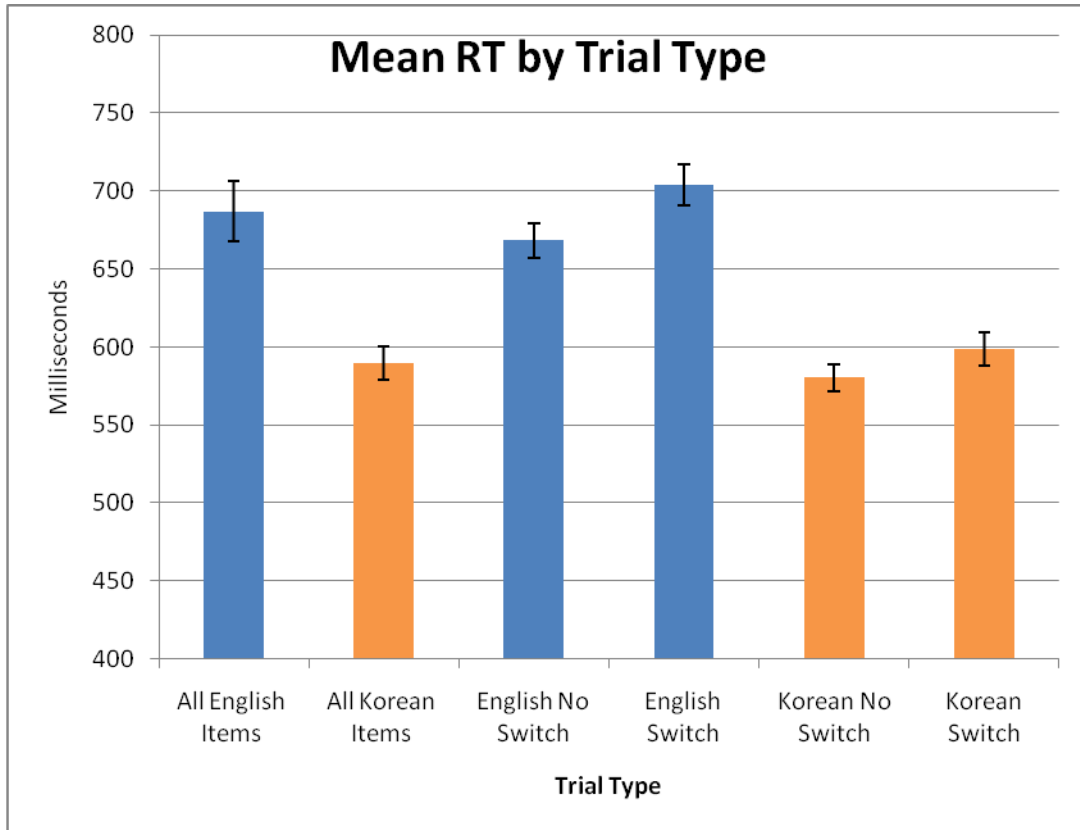


Figure 17. Lexical Decision Task mix block mean RTs by trial type

Examining switch costs for each language revealed asymmetric switch costs with an average English switch cost of 33.7 ms ($SD = 51.1$) and average Korean switch cost of 18.6 ms ($SD = 40.8$).

Table 13. Lexical Decision Task mixed block switch costs by language

ENG switch costs (Mean switch RT- ns RT)	KOR switch costs (Mean switch RT- ns RT)
$M = 33.7$ ms, $SD = 51.1$	$M = 18.6$ ms, $SD = 40.8$

While language switching negatively affected picture naming performance in both languages, the RT increase was slightly larger when switching into English, the participants' second language. The difference in switch costs was analyzed using a 2 x 2 ANOVA with the factors "Language" (Korean and English) and "Trial Type" (switch and non-switch). The main effects of Language ($F(1,65) = 175.0, p < .001$; $F(1,63) = 78.22, p < .001$) and Trial Type ($F(1,65) = 37.52, p < .001$; $F(1, 63) = 33.07, p < .001$) were significant. The F1 analysis for the interaction of Language and Trial Type also reached significance ($F(1, 65) = 5.81, p < .05$), but the F2 analysis for the interaction of Language and Trial Type was only marginally significant ($F(1,63) = 4.12, p = .047$).

Unlike the 5-block picture naming task in Experiment 1, there was no reversal of mean reaction time advantage for any block in the Lexical Decision task. That is, the mean reaction time for initial single-language blocks, the critical mixed block, and the final blocks all demonstrate faster responses in Korean. The final single language blocks (the second all-Korean and all-English blocks) resemble the initial single language blocks, with a faster overall mean RT for Korean items ($M = 638.8, SD = 95.7$) compared to the mean RT for English items ($M = 542.6, SD = 69.3$). ANOVA shows this difference to be significant ($F(1, 65) = 104.53, p < .001$; $F(1, 63) = 121.1; p < .001$).

A 2 (Language) x 2 (Block) Repeated Measures ANOVA was conducted to analyze overall repetition effects between the first and last single language blocks. The main effects of Language ($F(1, 65) = 181.40, p < .001$; $F(1, 63) = 116.04, p < .001$) and Block ($F(1, 65) = 206.16, p < .001$; $F(1, 63) = 192.97, p < .001$) were significant, as was the interaction of Language and Block ($F(1, 65) = 70.50, p < .001$); $F(1, 63) =$

60.01, $p < .001$). These results demonstrate a greater overall repetition effect for English compared to Korean in the Lexical Decision Task.

9.1.7 Discussion

The results from the Lexical Decision task will be discussed as they relate to each of the three research questions associated with this task.

RQ1. Does language switch cost asymmetry exist in Lexical Decision and Semantic Categorization tasks?

H1: Asymmetric switch costs will be observed in the Lexical Decision task, with switches into the L2 faster than switches into the L1. Switch cost asymmetry is expected for both production and non-production tasks.

Examining switch costs for each language (Mix Block switch mean RT minus Mix block non-switch mean RT) revealed asymmetric switch costs with an average English switch cost of 33.7 ms ($SD = 51.1$) and average Korean switch cost of 18.6 ms ($SD = 40.8$). While language switching affected picture naming performance in both languages, the RT increase was slightly larger when switching into English, the participants' second language. This significant difference is noteworthy because it marks the Lexical Decision Task as the only task to demonstrate significantly slower reaction times when switching from Korean (L1) to English (L2). To review, the 5-block Standard Picture Naming task produced asymmetric switch costs with a significantly faster mean switch cost to second language items compared to switches to the first language. This was the expected pattern as faster switches into the less dominant language have been demonstrated in past bilingual language switching studies, and this is the pattern

predicted by Green's (1998) Inhibitory Control model. Results from the Go No-Go picture naming task show no statistically significant differences in switch cost magnitude between switches into Korean (L1) and switches into English (L2). Therefore, to this point, switch-related results have been mixed, with data from one study demonstrating (expected) faster switches into the less dominant language, and results from the second study showing no significantly different switch costs between first and second language picture naming. The Lexical Decision Task is therefore the first task to demonstrate significant mean switch cost differences that were opposite of the predicted faster switches into L2.

One possible explanation for the novel switch cost pattern in the Lexical Decision task is differential semantic processing demands between the three tasks reviewed to this point. Examining the three tasks, it can be argued that the task requiring the least semantic processing would be the Lexical Decision task because the participants simply had to decide whether presented stimuli formed a word or not. On the other hand, a robust literature exists regarding the critical role of semantic processing in picture naming (e.g., Glaser, 1992; Maess, Friederici, Damian, Meyer, & Levelt, 2002). If semantic processing were a key factor in switch cost asymmetry, one might expect to see more robust switch cost asymmetry for tasks requiring extensive semantic processing and less robust differences, or symmetrical switch costs, for tasks requiring less extensive semantic processing. The results from the Standard Picture Naming fit this pattern well. Results from the Go No-Go task seem to contradict expected results, but it can be argued that the need to name only one of the response languages contributed to the lack of switch cost asymmetry in that task. Finally, a lack of L2 advantage in switch costs (or even L1

advantage) would not be surprising for tasks that require only very shallow semantic processing such as a simple Lexical Decision Task. In summary then, the pattern of results from the three tasks reviewed so far support the possibility that switch cost patterns, and bilingual switch task processing more generally, are affected by the type of task (productive vs. receptive) as well as the relative degree of semantic involvement required. This possibility will be addressed in more detail in the General Discussion section.

RQ2: Does the L2 RT advantage and L1 RT disadvantage carry over to subsequent single-language blocks in the Lexical Decision and Semantic Categorization Tasks?

H2: Yes. Mean reaction times for final single-language blocks will both be significantly faster than mean RTs for the initial single-language blocks due to practice effects. In addition to a general practice effect, the L2 advantage and L1 disadvantage will carry over to the final single-language blocks and result in a greater overall RT decrease for L2 compared to L1 (as measured by initial single-language block 1 Mean RT – final single-language block Mean RT). The expectation is that this effect will be observed for both lexical decision and semantic categorization tasks, representing a carry-over inhibitory effect above simple reactive inhibition that would remain isolated in the mixed condition.

Unlike the 5-block picture naming task in Experiment 1, there was no reversal of mean reaction time advantage for any block in the Lexical Decision task. That is, the mean reaction time for initial single-language blocks, the critical mixed block, and the final blocks all demonstrate faster responses in Korean. The final single language blocks (the second all-Korean and all-English blocks) resemble the initial single language blocks,

with a faster overall mean RT for Korean items ($M = 638.8$, $SD = 95.7$) compared to the mean RT for English items ($M = 542.6$, $SD = 69.3$). ANOVA shows this difference to be significant ($F(1, 65) = 104.53$, $p < .001$; $F(1, 63) = 121.1$; $p < .001$).

In addition to differences between initial single-language blocks, A 2 x 2 Repeated Measures ANOVA conducted to analyze repetition effects between the first and last single language blocks demonstrated a greater repetition effect for English compared to Korean initial and final blocks in this task. These results are also consistent with expectations based on past findings of increased repetition effects for L2 (less-dominant language) compared to the more dominant L1.

RQ3. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual language switching tasks?

H3: Yes. A significant negative correlation will exist between switch costs on the two receptive bilingual processing tasks (lexical decision and semantic categorization) and cognitive control ability as measured by the Simon Task.

Correlations were examined between participant Simon Task scores and switch and mix costs for both Korean and English stimuli. No significant correlations were found when calculating correlations between Simon Task scores and mix and switch costs for either language. In fact, no correlations neared significance for any of the targeted correlations in Experiment 1, Experiment 2, and thus far in Experiment 3.

9.2 Semantic Categorization Task

The primary purpose of this task was to investigate potential differences in mix costs, switch costs, and bilingual advantage in a non-production task requiring increased semantic processing compared to a simple word vs. nonword lexical decision. The research questions addressed by the Semantic Categorization task are also addressed by the Lexical Decision task:

RQ1. Does language switch cost asymmetry exist in Lexical Decision and Semantic Categorization tasks?

RQ2. Does the L2 RT advantage and L1 RT disadvantage carry over to subsequent single-language blocks in the Lexical Decision and Semantic Categorization Tasks?

RQ3. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual language switching tasks?

Method

9.2.1 Participants

Participant information is identical to that reported in section 9.1.1.

9.2.2. Design

The Semantic Categorization task is composed of 5 blocks. The initial two blocks are single-language blocks, followed by a mixed block and two final single-language blocks (see Figure 18).



Figure 18. Semantic Categorization Task block order

The order of language presentation (L1 or L2) was counterbalanced. As described above, each category contained 10 English YES response items, 10 Korean YES responses (translations of the English YES responses), and an equal number of English and Korean NO responses. For the initial English language block, half of the critical items for each category (5 items) were presented to the participant, with the other half of the items (i.e., the remaining 5 items) presented during the Korean language block. This created 20 YES responses per participant for each initial single-language block (4 categories x 5 YES responses). For the mixed block, all YES and No items from each of the initial single-language blocks were presented once again in a fixed order. Stimuli were presented in a fixed order to control which items appeared as switch trials, and lists were counterbalanced so that each critical YES item appeared as a switch trial for half of

the participants and a non-switch trial for the other half (see Mixed block lists and orders in Appendix F and G)

9.2.3. Materials

Five semantic categories were selected for this task: TRAVEL, OCCUPATION, WEATHER, FAMILY, and BODY PARTS. For each of the five semantic categories, 10 English words representing members of the category were selected and included in the task (e.g., 10 different occupations for the occupation category). Translation equivalents were used to create the Korean list. These 100 items (50 English/ 50 Korean) were the YES responses in the Semantic Categorization Task. An equal number of NO responses (50/50) were selected for this task so that YES and NO responses were matched for syllable length and frequency. Of the 5 semantic categories developed, 1 category list (TRAVEL) was used as practice for all participants and the remaining 4 categories were used as stimuli items that were scored and included in the analyses. Therefore, the total number of critical stimuli words for this task was 160 (40 YES English response items, 40 YES Korean translation equivalents, and 40 English and Korean NO responses).

9.3.4 Scoring and Analysis

Low cut-off points for reaction times were first set at 100ms, and responses with reaction times falling under 100ms were discarded. (The reaction times automatically stopped at the upper cut off of 3000ms, so only the lower cutoff was set during scoring.) The participant mean and standard deviations were then computed and values +/- 3 SDs from the mean were removed.

As with the 5-block picture naming task, repeated measures ANOVA was used to compare semantic categorization reaction times between L1 and L2 blocks, first single-language blocks and final single-language blocks, as well as between languages in the mixed condition. Switch costs were measured and analyzed for switch asymmetry in the critical mixed language block. As with the previous 5-block tasks, potential carry-over effects of the mixed block L2 advantage were also examined in the final two single-language blocks.

9.2.5 Procedure

The Semantic Categorization task was presented using E-Prime 2.0 (PST, Pittsburgh, PA). Prior to the start of the task, participants were told that they would see words presented on a screen, one at a time, and that they should decide as quickly and accurately as possible whether the word is a member of a given category. For example, for an initial practice trial, they were instructed to read a presented word and decide if it was a type of fruit. Participants were instructed to press the right shift key (marked YES) if the word was a member of the given category and the left shift key (marked NO) if the word was not a member of the category. Using the example of the category “Fruit,” participants should press the right shift key (YES) for the word “orange,” and the left shift key (NO) for the word “bus.” Participants were instructed to keep a finger positioned on each shift key throughout the duration of the experiment so that they could respond as quickly as possible. The critical categorization blocks were preceded by a practice block in order to familiarize the participants with the task. The practice block could be repeated as many times as required for the participants to feel comfortable with

the task and appropriate response mapping on the keyboard. However, no participant chose to repeat the practice block. Stimuli appeared in the center of the computer screen in black 20-point Times New Roman font on a white background. Stimuli remained on the screen until either a response was detected or 3 seconds had elapsed. If no response was detected after 3 seconds, the item timed out and the next stimulus item appeared after a 500 ms delay.

9.2.6 Results

Overall, mean accuracy for English YES responses was 95%, and mean accuracy for Korean YES responses was 97%. No participants were removed from analyses due to low accuracy. However, an E-Prime programming error caused the program to skip one of the five critical blocks for 7 participants. These 7 participants were dropped from analyses completely. In addition, one participant was unable to complete the testing session due to a family emergency. That individual completed all tasks with the exception of the Semantic Categorization and Lexical Decision tasks. Due to the loss of this participant and the 7 participants dropped due to the programming error, the total N size for this task was 62.

Mean reaction times for each of the five blocks are presented in Table 14.

Table 14. Semantic Categorization Task mean reaction times by block and language

All English Block 1	All Korean Block 1	Mix Block English	Mix Block Korean	All English Block 2	All Korean Block 2
<i>M</i> = 713.9 (102.7)	<i>M</i> = 626.5 (99.3)	<i>M</i> = 628.2 (99.2)	<i>M</i> = 585.9 (79.8)	<i>M</i> = 605.8 (83.1)	<i>M</i> = 565.3 (81.7)

The mean reaction time for correct responses in the first English block was 713.9 ms ($SD = 102.7$) and the mean reaction time for the first Korean block was 626.5 ms ($SD = 99.3$). A repeated measures ANOVA showed this difference to be significant ($F(1, 61) = 75.56, p < .001$; $F(1, 19) = 12.63, p < .05$).

The mean reaction time for correctly named Korean pictures ($M = 589.9, SD = 79.8$) was also faster than English pictures ($M = 628.2, SD = 99.3$) in the critical mixed block. Analysis of variance revealed a significant difference for participants ($F(1, 61) = 23.66, p < .001$) and for items ($F(1, 19) = 6.68, p < .05$).

To illustrate the differences between the initial single language blocks and the mixed block, mean reaction times for each block of the Semantic Categorization task are presented in figure 19.

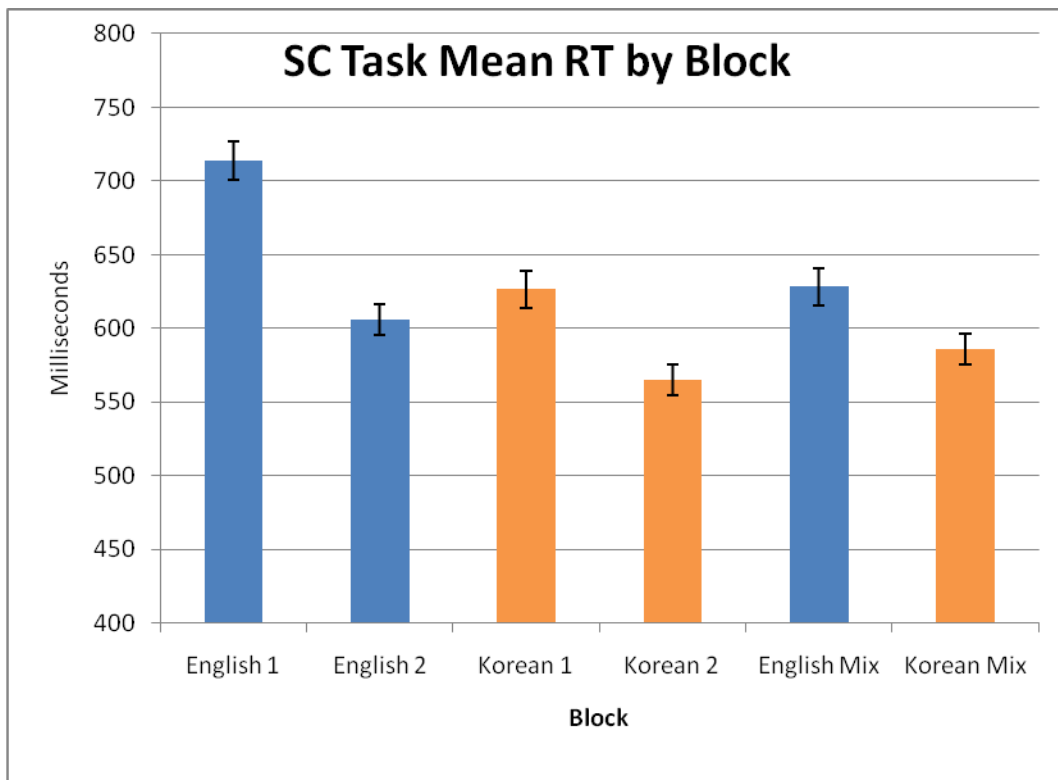


Figure 19. Semantic Categorization Task mean RTs by block

Within the Mixed Block, mean reaction times varied by language and trial type.

Table 15 displays mean reaction times within the critical Mixed Block.

Table 15. Semantic Categorization Task mix block mean RTs

Mix BK All English	Mix BK All Korean	Mix BK ENG Non-Switch	Mix BK ENG Switch	Mix BK KOR Non-Switch	Mix BK KOR Switch
$M = 628.2$ (99.2)	$M = 585.9$ (79.8)	$M = 619.1$ (88.9)	$M = 637.3$ (118.0)	$M = 575.8$ (85.3)	$M = 596.2$ (88.9)

Mix costs, presented below in Table 16, were calculated by subtracting the Mean RT for the initial single language block from the Mean RT of non-switch Mixed Block pictures for both Korean and English.

Table 16. Semantic Categorization Task English and Korean mix costs

English Mix Costs	Korean Mix Costs
$M = -94.8$ ms, $SD = 84.1$	$M = -50.7$ ms, $SD = 70.6$

Analysis of Variance revealed a significant difference ($F(1,61) = 15.16$, $p < .001$; $F(1, 19) = 5.96$, $p < .05$) between Korean ($M = -50.7$ ms, $SD = 70.6$) and English ($M = -94.8$ ms, $SD = 84.1$) mix costs. A 2 (Language) x 2 (Block) Repeated Measures ANOVA showed a significant main effect of Language ($F(1,61) = 67.83$, $p < .001$.; $F(1,19) = 22.58$, $p < .001$) and Block ($F(1,61) = 81.25$, $p < .001$; $F(1,19) = 12.99$, $p < .05$) and a significant interaction between Language and Block ($F(1,61) = 15.16$, $p < .001$; $F(1,19) = 6.48$, $p < .05$). Mix Block results are illustrated in Figure 20.

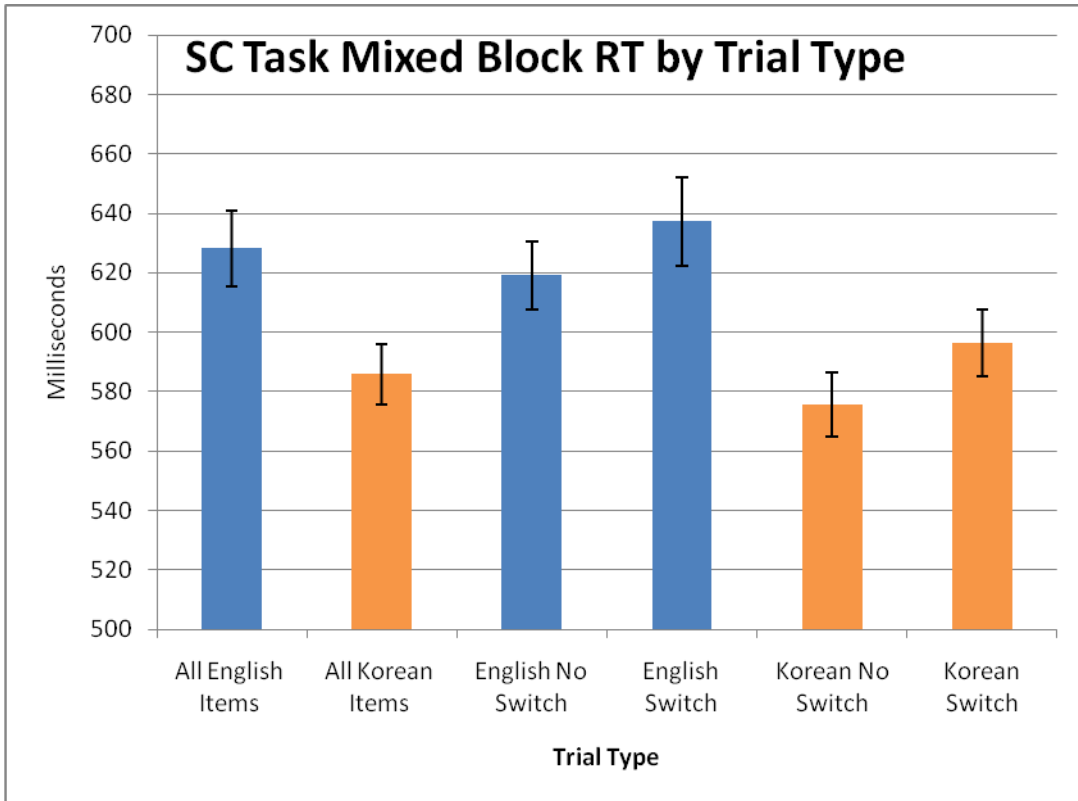


Figure 20. Semantic Categorization Task mix block mean RTs by trial type

Mean switch costs are presented below in Table 17. The mean switch costs into English was 18.2 ms ($SD = 64.8$). Switching from English to Korean items resulted in a nearly identical switch cost ($M = 20.1$ ms, $SD = 69.9$).

Table 17. Semantic Categorization Task mean switch costs

English switch costs	Korean switch costs
18.2 ms ($SD = 64.8$)	20.1 ms ($SD = 69.9$)

A 2 x 2 Repeated Measures ANOVA with the factors Language and Switch Type revealed a significant main effect for Language ($F(1,61) = 23.66, p < .001$; $F(1,19) = 18.66, p < .001$) and Switch Type ($F(1,61) = 7.29, p < .05$; $F(1,19) = 21.47, p < .001$), but no significant interaction effect ($F(1,61) = .058, n.s$; $F(1, 9) < .24, n.s.$).

Unlike the 5-block picture naming task in Experiment 1, there was no reversal of mean reaction time advantage for any block in the Semantic Categorization task. That is, the mean reaction time for initial single-language blocks, the critical mixed block, and the final blocks all demonstrate faster responses in Korean. The mean reaction times for the final single language blocks were 605.8ms ($SD = 83.1$) and 565.3 ms ($SD = 81.7$) for Korean. ANOVA shows this difference to be significant ($F(1,61) = 18.06, p < .001$; $F(1,19) = 10.16, p < .05$).

A 2 x 2 Repeated Measures ANOVA with the factors Language (English and Korean) and Block (First and Last) was conducted to analyze repetition effects between the first and last single language blocks. Results show a significant main effect of Language ($F(1,61) = 61.39, p < .001$; $F(1,19) = 18.65, p < .001$) and Block ($F(1,61) = 108.97, p < .001$; $F(1, 19) = 41.01, p = .001$), as well as a significant interaction effect ($F(1,61) = 18.96, p < .001$; $F(1, 19) = 5.90, p < .05$). These results demonstrate a greater repetition effect for English compared to Korean in the Semantic Categorization Task.

9.2.7 Semantic Categorization Discussion

Results from the Semantic Categorization Task will be discussed as they relate to the three research questions for this Experiment.

RQ1. Does language switch cost asymmetry exist in the Lexical Decision and Semantic Categorization tasks?

H1: Asymmetric switch costs will be observed in the Lexical Decision task and Semantic Categorization task, with switches into the L2 faster than switches into the L1. Switch cost asymmetry is expected for both production and non-production tasks.

Past switch studies have demonstrated consistent asymmetric switch costs for unbalanced bilinguals performing picture naming tasks (e.g., Costa & Santesteban, 2004; Costa et al., 2006; Meuter & Allport, 1999; Schwieter & Sunderman, 2008). Results from the Experiment 1 Picture Naming Task provide further support for asymmetric switch costs in traditional picture naming tasks. To the author's knowledge, no past studies contain a design similar to the Semantic Categorization task utilized in this experiment. However, based on consistent asymmetric switch costs for unbalanced bilinguals in past picture naming studies (and the results of Experiment 1 testing the same population as the current study), it was expected that participants in the current study would also demonstrate asymmetric switch costs on the Semantic Categorization Task. Data from this task demonstrate no switch cost asymmetry.

In the critical Mixed Block, the mean switch costs into English was 18.2 ms ($SD = 64.8$). Switching from English to Korean items resulted in a nearly identical switch cost ($M = 20.1$ ms, $SD = 69.9$). A 2 x 2 Repeated Measures ANOVA demonstrated no significant interaction effect for F1 or F2 analyses, showing no significant differences in

switch costs between languages. These results are counter to expectations and raise interesting questions regarding processing differences between production tasks such as picture naming tasks and receptive tasks such as Semantic Categorization.

Based on the results from the three tasks detailed so far (Standard Picture Naming, Go No-Go Picture Naming, and Lexical Decision), a possible explanation for the lack of asymmetric switch costs may lie in the need to produce a verbal response. That is, switch cost asymmetry existed in the Standard Picture Naming task, where participants were required to verbally respond to picture stimuli in both languages, but not in the Go No-Go task or the Lexical Decision Tasks. This potential explanation will be discussed in more detail in the General Discussion section.

RQ2. Does the L2 RT advantage and L1 RT disadvantage carry over to subsequent single-language blocks in the Lexical Decision and Semantic Categorization Tasks?

H2: Yes. Mean reaction times for final single-language blocks will both be significantly faster than mean RTs for the initial single-language blocks due to practice effects. In addition to a general practice effect, the L2 advantage and L1 disadvantage will carry over to the final single-language blocks and result in a greater overall RT decrease for L2 compared to L1 (as measured by initial single-language block 1 Mean RT – final single-language block Mean RT). The expectation is that this effect will be observed for both lexical decision and semantic categorization tasks, representing a carry-over inhibitory effect beyond simple reactive inhibition that would remain isolated in the mixed condition.

Unlike the initial 5-block Standard Picture Naming Task, the Semantic Categorization Task shows no L2 advantage in any of the five critical blocks. That is, mean Korean block reaction times are faster than mean English block reaction times for all blocks. However, closer examination of reaction time speed-up between blocks shows that, once again, English (L2) items benefited more from item repetition than Korean (L1) items based on block mean reaction times. This can be seen in mix costs, which compare reaction time differences between initial single-language block mean reaction time and mean reaction time for Mix Block non-switch items. Korean items showed no mixed block disadvantage when compared initial single language processing. In fact, mean reaction time for Korean items actually decreased 50.7 ms between the initial all-Korean block and the mixed block. However, once again, English items demonstrated a faster speed-up, with a mean reaction time decrease of 94.8 ms between initial all-English items and English items in the Mixed Block.

In addition to differences between initial single-language blocks and the critical mixed block, A 2 x 2 Repeated Measures ANOVA conducted to analyze repetition effects between the first and last single language blocks demonstrated a greater repetition effect for English compared to Korean initial and final blocks in this task. These results are also consistent with expectations based on past findings of increased repetition effects for L2 (less-dominant language) compared to the more dominant L1. And, as was the case in Experiments 1 and 2, data from the Semantic Categorization Task demonstrate no separate L1 processing disadvantage in the mixed block, and no “carry-over” disadvantage affecting the final single-language blocks.

RQ3. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual language switching tasks?

H3: Yes. A significant correlation will exist between switch costs on the two receptive bilingual processing tasks (lexical decision and semantic categorization) and cognitive control ability as measured by the Simon Task.

Correlations were examined between participant Simon Task scores and switch and mix costs for both Korean and English stimuli. No significant correlations were found when calculating correlations between Simon Task scores and mix and switch costs for either language.

As was previously discussed, it is believed that a link may exist between general cognitive control ability and language control required in bilingual processing tasks. If this were the case, one might expect to see significant correlations between performance on the Simon Task and mix and switch costs in bilingual picture naming task. More specifically, individuals with higher mean Simon Effect scores, which reflect a relatively poorer ability to overcome prepotent responses, might be expected to demonstrate greater switch costs in the bilingual processing tasks. However, no significant correlations were found between Simon Task performance and switch costs in the Semantic Categorization task. In fact, no correlations neared significance for any of the targeted correlations in Experiment 1, Experiment 2, or Experiment 3.

9.3 Simon Task

As detailed in Section 7.4, the Simon Task was used as a measure of general cognitive control. The same task was administered to 69 of 70 participants tested in Experiments 1 and 2, and task details and procedures are as presented in Chapter 7.

9.3.1 Scoring

The RT difference score between congruent and incongruent trials was computed and was used as a measure of participants' inhibitory control ability in order to investigate the possible connection between language switch performance and general cognitive control.

Only correct responses were counted, and scores above or below 3 standard deviations were removed the analysis. After scoring was complete, a correlation was run between participant Simon Scores and switch and mix costs incurred during the Semantic Categorization Task.

9.3.2 Results

Participants from both Experiments reported little difficulty with the Simon Task. The mean accuracy for the 69 participants tested was nearly 97%, and the mean Simon Effect was 34 ms (SD = 26.1). Although the mean Simon effect reflected generally slower responses for incongruent responses compared to congruent, the actual effect varied greatly between participants. The greatest slowdown observed was approximately 84 ms, but several scores reflected little to no change between conditions. Four

participants of the 69 tested demonstrated slightly faster reaction times for incongruent stimuli, but the effect was relatively small in all four cases (range = -12 to -18ms).

Correlations were examined between participant Simon Task scores and mix and switch costs for both Korean and English stimuli in the Semantic Categorization Task. No significant correlations were found when calculating correlations between Simon Task scores and 1. Korean switch costs, 2. English switch costs, 3. Korean mix costs, and 4. English mix costs. No significant correlations were found between Simon Task performance and switch costs in the picture naming task. In fact, no correlations neared significance for any of the four correlations run.

9.4 Lexical Robustness Measure

The verbal proficiency measure included in this study was adapted from Schwieter & Sunderman (2008) and was designed to provide a measure of participants' vocabulary knowledge. This measure, based on the experimental procedures of Gollan, Montoya, and Werner (2002), is described as a method of operationalizing the "robustness of the L2 lexicon" (Schwieter & Sunderman, p. 223). Costa et al. (2006) also refer to "lexical robustness" and defined it as the familiarity with and frequency of access that leads to greater automaticity of lexical retrieval. The task was verbally administered to the participant by the researcher, who provided a category for which the participant provided (orally) as many examples as possible in one minute. There were a total of ten categories, and the total score was calculated by adding the number of all correct responses to determine an overall score. Duplicate answers and answers outside of the required category were not counted toward the final score.

The verbal fluency measure was included in this study for two reasons. First, the number of category-specific items an individual can produce within one minute could be used as additional information to better estimate participants' vocabulary knowledge. While this measure does not provide a full measure of a participant's global L2 proficiency, it does produce useful information that, when combined with data from the language history questionnaire, provides a reasonable estimation of L2 vocabulary knowledge in a short period of time. Second, Schweiter and Sunderman (2008) used this measure to investigate where along the continuum of lexical robustness participants moved from reliance on inhibitory control to more language-specific processing. As the research questions of the current study overlap significantly with the core questions in Schweiter and Sunderman's (2008) investigation into bilingual language selection, the use of the same proficiency measure for a different population may produce useful data for future studies on this issue.

9.4.1 Results

A total of 70 participants completed this task, and the mean final score was 141 ($SD = 24.6$). It is important to note that Lexical Robustness scores varied greatly between the participants, with a minimum score of 95 and a maximum score of 201. As was the case when data from Experiments 1 and 2 were examined separately, there was no apparent relationship between Lexical Robustness scores and education level (e.g., undergraduate students vs. post-doctorate fellows), nor was there a significant relationship between Lexical Robustness scores and time in the United States when data from all 70 participants were combined. The average age at which the 70 participants

began learning English in Korea was approximately 11.5 years ($SD = 2.3$). The overall correlation between starting age for English language education (in Korea) and Lexical Robustness scores was $-.401$, ($p < .001$).

10 General Discussion

The three experiments detailed in Chapters 7, 8, and 9 provide new data related to mix and switch costs in second language processing. In this chapter, this project's ten research questions will be presented and patterns of results from across the three experiments will be discussed. After consolidating and discussing key results, findings from this study will be compared with results from past studies and critical aspects of models such as the Inhibitory Control Model (Green, 1998).

In order to best shape the current discussion about results from this study, the ten research questions will first be presented, and then broken into four main groups for further discussion. The ten research questions this study was designed to investigate are as follows:

RQ1. Does switch cost asymmetry exist when naming pictures in a mixed language condition (Korean and English) of a standard picture naming task?

RQ2. Do reaction times in the mixed block of picture naming tasks show an L2 reaction time advantage and L1 reaction time disadvantage for non-balanced bilinguals?

RQ3. Does the L2 reaction time advantage in the mixed block carry over to subsequent single-language block L2 picture naming?

RQ4. If the L2 reaction time advantage in the mixed block carries over to subsequent single-language block L2 picture naming, does the effect differ between previously named (old) and novel (new) pictures?

RQ5. Does the L2 reaction time advantage and L1 disadvantage persist in a Go-No Go variant of the picture naming task in which participants only verbally respond to one of the two languages?

RQ6. Do switch costs exist in a Go-No Go variant of the picture naming task in which participants only respond to one of the two languages?

RQ7. Does language switch cost asymmetry exist in Lexical Decision and Semantic Categorization tasks?

RQ8. Do reaction times in the mixed blocks of Lexical Decision and Semantic Categorization Tasks show an L2 reaction time advantage and L1 reaction time disadvantage for non-balanced bilinguals?

RQ9. Does the L2 RT advantage and L1 RT disadvantage carry over to subsequent single-language blocks in the Lexical Decision and Semantic Categorization Tasks?

RQ10. Does performance on a general inhibitory control task (Simon Task) correlate with task switching performance on bilingual language switching tasks (Semantic Categorization and Lexical Decision)?

These ten research questions can be divided into the following three main focus areas:

1. L2 advantage (and potential L2 disadvantage) in mixed language environments (Language mix effects)
2. Symmetry or asymmetry of language switch costs (Language switch effects)
3. Influence of individual differences on bilingual mix and switch processing

These three research foci will be discussed in turn, starting with an overview of mix cost-related findings.

10.1 Overview of Mix Cost Findings

All four main tasks included in this study were designed to examine the effects of a mixed language environment on bilingual language processing. Experiment 1 included what can be considered the most traditional task in terms of investigations into mixed language processing: the Standard Picture Naming Task. This task included several blocks of single language picture naming and, critically, a middle mixed-block where both Korean and English pictures were named. The picture naming task in Experiment 2 was similar, but included the key manipulation of participants only naming pictures in one of the two target languages presented in the mixed blocks. This manipulation was added to more closely examine the source of mix costs. That is, do mix costs result from the need to prepare and verbalize responses to both the L1 and L2, or is it simply the

presence of two languages that creates mix effects in bilingual picture naming tasks. The third task was the Semantic Categorization task presented in Experiment 3. This task was similar in structure and purpose to the Standard Picture Naming Task in Experiment 1. However, a key difference is removal of the requirement to produce a verbal response. The Semantic Categorization Task was included as a receptive task that required no verbal responses throughout the task, and was designed to identify potential mix effect differences between production and receptive tasks. Although no verbal responses were required for this task, semantic processing was still required to complete the task. This differentiates the Semantic Categorization Task from the other receptive task in Experiment 3, the Lexical Decision Task. While it is not claimed that the Lexical Decision Task is totally free from semantic processing, the semantic processing demand is likely much lower for simple word-nonword decisions than decisions involving both identification of words and semantic categorization judgments as found in the Semantic Categorization Task. In summary, while the four main language processing tasks used in this study are all similar to the extent that they were designed to investigate mix and switch costs, they differ in terms of production and semantic processing requirements.

The question then becomes what pattern of results would emerge from these four tasks based on the extant literature. The task with the clearest predictions was the Standard Picture Naming Task from Experiment 1. This task was designed to examine switch costs, mix costs, and any potential carry over from changes in mixed block processing to final single-language block picture naming. Regarding mixed costs in this task, two main predictions were made. Based on the previous literature on mix costs in bilingual picture naming (e.g., Christoffels et al., 2006; Kroll, Michael, Tokowicz, and

Dufour, 2002; Phillip, Gade, & Koch, 2006) and results of the pilot study, L1 single-language block mean reaction times were expected to be faster than single-language L2 block reaction times. Also, reaction times for correctly named L2 pictures in the mixed block for the Standard Picture Naming task in Experiment 1 were expected to be faster than correctly named L1 pictures in the mixed block. Both of these predictions were supported by the data from Experiment 1. The mean reaction time for correct responses in the first English block was significantly slower than the mean reaction time for the first Korean block in Experiment 1. This was expected, and provides additional evidence that when L1 picture stimuli are named separately (i.e., not mixed together in the same block), L1 pictures are consistently named faster than L2 (or weaker language) pictures. In contrast to the faster reaction times for Korean (L1) pictures in single-language blocks, the mean reaction time for correctly named Korean pictures was slower than English pictures in the critical mixed block.

In addition to the differences in mean naming latencies, the costs associated with mixing stimuli also differed by language. A significant difference existed between mix costs with Korean stimuli named more slowly in the mixed condition and English stimuli named faster in the mixed condition. This difference revealed a striking contrast with L1 picture naming not significantly affected by the mixed condition (i.e., no significant increase or decrease in reaction time), while L2 picture naming clearly benefited from the mixed environment. It is important to note here that switch items were excluded from this analysis to avoid confounding mix and switch effects. Without separating the switch effects from the mix effects, the results from the mixed block would differ significantly; however, this would incorrectly (and unnecessarily) include the related, but separate,

effect of language switching. It is also important to note, when examining “mix costs,” that the multi-block design of tasks in this study caused the confounding of mix effects and repetition effects. This is due to the fact that all items in mix blocks in this experiment had already been named one time in preceding single-language blocks. Therefore, what is referred to as “mix effects” is actually a combination of mix effects as traditionally defined (i.e. cost of processing two languages in a single block) plus repetition effects for items named in an initial single language block and then again in the mixed block. Therefore, a “mix effect” of -50 ms, for example, can be the result of the mixed language environment, repetition effects, or (most likely) both.

Results from past studies have suggested both an L2 advantage and L1 disadvantage in mixed language conditions. The benefit to L2 processing was very clear, with L2 pictures named significantly faster than L1 pictures in the mixed block. However, the notion of an L1 disadvantage did not appear to be supported by the data. The mean reaction time for Korean pictures was approximately 30 ms faster in the mixed block for non-switch items compared with the initial all-Korean block. While this difference did not represent a significant speed up, neither did it represent a significant slowdown. If an L1 processing disadvantage did exist in the mixed block, one would expect a slower mean reaction time for mixed block L1 items compared with initial single-language block reaction times. However, the data from this study showed no such disadvantage.

Instead of a simple L2 advantage/ L1 disadvantage explanation for Mixed Block picture naming, results from this study suggest an explanation that involves a robust L2 processing advantage and a minimal effect on L1 that did not reach statistical

significance in this study. As discussed in Chapter 7, repetition priming effects appear to offer a solid explanation for the results of Experiment 1. There was a small, but insignificant, repetition effect of approximately 35 ms for L1 items between the first and second blocks (non-switch items). English pictures demonstrated a much greater repetition effect for previously named items in the mixed block, which was expected based on previous research (e.g., Alvarez, Holcomb, & Grainger, 2003; Hernandez, Bates, and Avila, 1996). The old/new picture manipulation in the final block of the Standard Picture Naming Task provides further evidence of differential repetition effects. Repetition effects from the three presentations of previously seen English pictures (old pictures) lowered the reaction times of English pictures to the point where the mean reaction time for old items in the final block did not differ significantly from old Korean pictures. However, novel English pictures (new pictures) demonstrated a mean reaction time near the mean reaction time for English items in the first block. This demonstrates that, despite significantly faster mean reaction times for Korean items compared to English items in the initial single-language blocks, the differential effects of repetition sped up the reaction time of English items to the point that they were not significantly different from Korean items after only the third presentation.

In summary, Experiment 1 demonstrated a robust processing advantage for L2 items in the critical mixed block and a non-significant speed up for Korean items. These results are presented in Table 18.

Table 18. Standard Picture Naming mean English and Korean mix costs

English Mix Costs	Korean Mix Costs
-248.1ms (<i>SD</i> = 158.1)	-34.5ms (<i>SD</i> = 212.7)

As the Go No-Go Picture Naming Task utilized the same stimuli (except for 3 replacement items), initial single-language picture naming performance was expected to mirror that of the Standard Picture Naming Task in Experiment 1. While some variation in overall reaction times could be expected, there was little reason to suspect that the L1 dominance in single language blocks seen in Experiment 1 would not also exist in Experiment 2. In fact, the Go-No Task did show the exact same pattern, with the mean reaction time for the initial Korean block almost 200 ms faster than the mean reaction time for the initial all-English block.

What was not as clear, however, was how processes underlying picture naming in a mixed language environment might change due to the requirement to name only one of the two languages presented in the block. It was predicted that data from the Go No-Go mixed block would mirror data from the Standard Picture Naming Task, showing an L2 advantage and L1 disadvantage for reaction times in that block. This prediction proved to be incorrect for two reasons. First, as discussed above, Korean items in the mixed block of the Standard Picture Naming Task were still named faster than the mean for the initial all-Korean block. While this was not a significant difference, it does not demonstrate a negative effect on non-switch Korean items in the mixed block. Second, no L2 reaction time advantage existed in the mixed block of the Go No-Go Task (i.e., mean reaction times for Korean items were faster than English items in both single language and mixed conditions).

The lack of L2 mixed block reaction time advantage can be explained by at least two different accounts. First, because responses were only required for one language in each block, it is possible that participants simply treated the Go No-Go mixed block as a

single-language block. However, the fact that the non-response items had already been presented, identified, and verbally responded to in an initial single-language block makes it seem unlikely that there was no activation for non-target language items in the mixed block. This account is made less likely by participant exit interviews that reported that some participants were silently naming non-target language pictures while waiting for the next target language stimulus. Although it is impossible to conclusively rule out the possibility that participants somehow managed to tune out the non-target language stimuli and treat the mixed block as a single language block, previous naming of non-target items and exit interview responses combine to suggest that this is highly unlikely. A more plausible explanation for lack of L2 mean reaction time advantage (compared to L1) in the mixed block might be that processes underlying response production contribute to the comparative L2 advantage. Removing the need to produce a response for both languages might, in fact, avoid the inversion of mean reaction time advantage found in Experiment 1 as well as past picture naming studies (e.g., Mueter & Allport, 1999, Costa & Santesteban, 2004). While data from this one task cannot provide a definitive answer, a combination of results from all four tasks is likely more informative. Based on the above account, reversal of overall mean reaction advantage from L1 to L2 would only be evident in one of the four tasks included in this study (Standard Picture Naming). As will be shown, the Standard Picture Naming Task from Experiment 1 is indeed the only task to show such a pattern.

While the Go No-Go task did not show a reversal, or inversion, of picture naming advantage from L1 to L2 in the mixed blocks, there was a clear and significant difference in repetition effects. Analyzing the mix costs for each language in the Go No-Go Task,

English once again demonstrated a much greater repetition effect compared to Korean. This result was expected and, like the reaction time decrease across blocks in Experiment 1, can be explained by differential effects of repetition priming for L1 and L2 items (e.g., Alvarez, Holcomb, & Grainger, 2003; Hernandez, Bates, and Avila, 1996). A critical difference exists between repetition effects for Korean items when comparing Experiments 1 and 2, however. While no significant speed up existed from the Korean block to the mixed block in the Standard Picture Naming task, a marked decrease in reaction time was present for Korean items in the Go No-Go Task. As presented in Table 19, similarly large decreases in reaction time were observed for English items between blocks in the Standard Picture Naming Task and the Go No-Go Task. Critically, a significant speed up exists for Korean items in the Go No-Go Task but not the Standard Picture Naming Task. With the Go No-Go mean reaction time for Korean mixed items at 1177.9 ms, and the mean RT for English mixed items at 1121.7 ms, a difference of only 56 ms separated mean reaction times for the languages. It is interesting to note that without the speed up of 137.2 ms for Korean items between the single Korean and mixed block, an inversion of processing advantage would have appeared in the Go No-Go task (as was also the case with the Standard Picture Naming Task in Experiment 1). The question then becomes why the Go No-Go task demonstrated a significant speed up for Korean items between blocks while the Standard Picture Naming Task did not. The answer likely lies in the one main difference between the tasks; verbal responses for both languages were only required in the mixed block of the Standard Picture Naming Task.

Table 19. L1 and L2 mix costs in Experiments 1 and 2

Task (Experiment #)	English Mix Costs (<i>SD</i>)	Korean Mix Costs (<i>SD</i>)
Standard Picture Naming Task (1)	-248.1 ms (158.1)	-34.5 ms (212.7)
Go No-Go Task (2)	-260.6 ms (167.4)	-137.2 ms (205.2)

Turning to the Semantic Categorization Task in Experiment 3, results from this task are generally similar to results from the Go No-Go Task in Experiment 2. Like the Go No-Go task, the Semantic Categorization Task shows no L2 advantage in any of the critical blocks. That is, mean Korean block reaction times are faster than mean English block reaction times for all blocks. This is in contrast to the Standard Picture Naming Task in Experiment 1, in which L2 items were named faster than L1 items in the mixed block.

Further examination of mean reaction times demonstrate that, as with all tasks discussed so far, English (L2) items benefited more from item repetition than Korean (L1) items. This can be seen in mix costs, which compare reaction time differences between initial single-language block mean reaction time and mean reaction time for Mixed Block non-switch items. Korean items showed no mixed block disadvantage when compared to initial single language block processing. In fact, mean reaction time for Korean items actually decreased 50.7 ms between the initial all-Korean block and the mixed block. However, once again, English items demonstrated a faster speed-up, with a mean reaction time decrease of 94.8 ms between initial all-English items and English items in the Mixed Block.

In addition, analyzing repetition effects between the first and last single language blocks revealed a greater repetition effect for English compared to Korean initial and final blocks in this task. These results are also consistent with expectations based on past findings of increased repetition effects for L2 (less-dominant language) compared to the more dominant L1. And, as was the case in Experiments 1 and 2, data from the Semantic Categorization Task demonstrate no separate L1 processing disadvantage in the mixed block. Adding the results from the Semantic Categorization Task, mix costs for the first three tasks are presented below in Table 20.

Table 20. Mix costs summary for the first three processing tasks

Task (Experiment #)	English Mix Costs (<i>SD</i>)	Korean Mix Costs (<i>SD</i>)
Standard Picture Naming Task (1)	-248.1 ms (158.1)	-34.5 ms (212.7)
Go No-Go Task (2)	-260.6 ms (167.4)	-137.2 ms (205.2)
Semantic Categorization Task (3)	-94.8 ms (84.1)	-50.7 ms (70.6)

Results from the final task, the Lexical Decision Task, continue the pattern of no L2 mean reaction time advantage in the mixed block and larger repetition effects for L2 compared to L1. The mean reaction time for initial single-language blocks, the critical mixed block, and the final blocks all demonstrate faster responses in Korean. The final single language blocks (the second all-Korean and all-English blocks) also resemble the initial single language blocks, with a faster overall mean RT for Korean items compared to the mean RT for English items. Furthermore, analysis of repetition effects between the

first and last single language blocks demonstrated a greater repetition effect for English compared to Korean initial and final blocks in this task. Mix costs also resemble findings from earlier tasks. Korean non-switch items in the mixed block were named an average of 13 ms faster than items in the initial all-Korean block. While this is not significantly faster than reaction times in the first block, it is not slower either, as would be expected if a distinct L1 disadvantage existed in the mixed language condition. In summary, the results of the Lexical Decision Task are also consistent with expectations based on past findings of increased repetition effects for L2 (less-dominant language) compared to the more dominant L1.

The final table illustrating mix effects across all four tasks included in this study is presented in Table 21.

Table 21. Bilingual language processing tasks mix effect summary

Task (Experiment #)	English Mix Costs (<i>SD</i>)	Korean Mix Costs (<i>SD</i>)
Standard Picture Naming Task (1)	-248.1 ms (158.1)	-34.5 ms (212.7)
Go No-Go Task (2)	-260.6 ms (167.4)	-137.2 ms (205.2)
Semantic Categorization Task (3)	-94.8 ms (84.1)	-50.7 ms (70.6)
Lexical Decision Task (3)	-138.8 ms (99.1)	-13.3 ms (62.5)

Summarizing the mix-related results from Experiments 1-3, several patterns emerge. First, only one of the four tasks demonstrated a reversal of processing advantage for mixed block bilingual language processing. Only in the Standard Picture Naming Task is the L2 mean reaction time faster than L1 mean reaction time. In every other block, for every other task, mean reaction times for correctly named Korean responses are faster than mean reaction times for correctly named English items. This finding supports the possibility that the requirement to produce more than one language in a mixed language block underlies, or at least contributes to, the inversion of L1/L2 advantage reported in past studies that used picture (or digit) naming studies (e.g., Costa & Santesteban, 2004; Costa et al., 2006; Meuter & Allport, 1999).

An important trend that arises across the four tasks is greater repetition effects for L2 (English) items compared to L1 (Korean). This data provides further support to recent studies reporting increased repetition effects for second language compared to first (e.g., Alvarez, Holcomb, & Grainger, 2003; Duyck, Vanderelst, Desmet, & Hartsuiker, 2008; Hernandez, Bates, and Avila, 1996). The old/new picture manipulation in the final block

of the Standard Picture Naming Task provides further evidence of this effect. Repetition effects built over the three presentations of previously seen English pictures (old pictures) lowered the reaction times of English pictures to the point where the mean reaction time for old items in the final block did not differ significantly from old Korean pictures. However, novel English pictures (new pictures) demonstrated a mean reaction time near the mean reaction time for English items in the first block. This demonstrate that, despite significantly faster mean reaction times for Korean items compared to English items in the initial single-language blocks, the differential effects of repetition sped up the reaction time of English items to the point that they were not significantly different from Korean items after only the third presentation. Therefore, repetition effects represent a critical variable in mix and switch tasks that should be considered during task design as well as interpretation of results.

10.2 Overview of Switch Effects

In addition to mix effects, this study also investigated bilingual language switch effects, which refer to processing costs resulting from switching from one response language to another. In a seminal study, Meuter & Allport (1999) found asymmetric switch costs for low proficiency bilinguals, with switches into their native language taking longer than switches into their weaker second language. Several studies have replicated the finding of asymmetric switch costs for low-proficiency learners as well as extended the findings to include symmetrical switch costs for balanced bilinguals (e.g., Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Schwieter & Sunderman, 2008). With several other studies failing to replicate asymmetric switch costs

(e.g., Finkbeiner, Almeida, Janssen, & Caramazza, 2006; Gollan & Ferreira, 2009), examination of switch cost-related factors may allow for a better understanding of why switch costs arise, and how different task designs might affect results of task switch studies.

In addition to past studies demonstrating asymmetric switch costs for bilingual picture naming tasks, results from the pilot study reported in Chapter 5 provided further support for expected switch cost asymmetry for participants in the current study. Therefore, it was expected that participants completing the Standard Picture Naming Task in Experiment 1 would also demonstrate asymmetric switch costs.

Results from Experiment 1 are consistent with the pilot study and past studies showing asymmetric switch costs for non-balanced bilinguals. Examination of switch costs for each language revealed asymmetric switch costs with an average English switch cost of 62.25 ms ($SD = 102.7$) and average Korean switch cost of 111.62 ms ($SD = 123.2$). Both languages were negatively affected by switch trials, but the reaction time cost was greater when switching into the participants' first language.

Table 22. Standard Picture Naming Task switch costs

English Switch Costs	Korean Switch Costs
62.25 ms ($SD = 102.7$)	111.62 ms ($SD = 123.2$)

Based on results presented in Table 22, data from the Standard Picture Naming task provide additional evidence for asymmetric switch costs for non-balanced bilinguals. As was the case in the pilot study, these results are in line with predictions of Green's (1998) Inhibitory Control Model. That is, higher switch costs from the second language

to the more dominant first language in this study can be explained by the need to overcome higher levels of inhibition for L1 items. Critically, the Inhibitory Control Model was developed as a model of bilingual language production. Therefore, it was unclear how principles of this model would apply to receptive bilingual language processing tasks and, more specifically, if switch cost asymmetry would be expected.

Before results from the two receptive tasks are discussed, however, results from the second production task will be reviewed. The Go No-Go Picture Naming Task was, like the Standard Picture Naming Task, a production task in that it required participants to verbally produce names of picture stimuli. As a production task, it was predicted that results from this task would mirror results from the Standard Picture Naming Task in Experiment 1. This was not the case, however. Critical differences emerged after examination of Go No-Go task data, including a lack of significant switch cost asymmetry. Not only was no significant switch cost asymmetry found for this task, the data showed what appeared to be asymmetry in the direction opposite of what the Inhibitory Control Model would predict (although, again, this difference was not significant). The switch costs for the Go No-Go Task are added to results from the Standard Picture Naming task in 23 below.

Table 23. Experiment 1 and 2 switch effect summary

Task Name (Experiment)	English Switch Cost (SD)	Korean Switch Cost (SD)
Standard Picture Naming (1)	62.25 ms (102.7)	111.62 ms (123.2)
Go No-Go Picture Naming (2)	23.4 ms, (142.2)	-21.1 ms (130.5)

The lack of switch cost asymmetry in the Go No-Go task requires an explanation, especially considering the significant switch cost asymmetry found in the Standard Picture Naming Task completed by participants of generally similar proficiency and language background. The key difference between Experiment 1 and Experiment 2 tasks is the requirement to only name one language in the mixed condition in Experiment 2. Again, it is possible that participants completing the Go No-Go task simply treated the mixed blocks as single language blocks (as instructed). However, as previously discussed, exit interviews suggest that participants did in fact process the non-target language items in the non-target language. This, in combination with the fact that all non-target items were previously named in the non-target language, suggests that at least some activation would be likely despite the task instructions. It is also possible that participants were able to tune out the non-target language (e.g., shift to a “monolingual mode,” Grosjean, 2001). However, this seems unlikely based on mounting evidence suggesting that this language selection account is untenable (e.g., Dijkstra, 2005). The remaining explanation, then, would be that the requirement to name items in both languages contributes to language switch asymmetry. Levy et al.’s (2007) production-specific, phonological-inhibition account offers some support for this explanation. Additional support can be found in results from Gollan and Ferreira (2009), who claimed that the option to choose the response language nullified switch cost effects normally found in bilingual picture naming. Regarding the findings from that study, it is possible that responding in only one language at a time removed the interference normally associated with competition for selection between lexical items of the bilingual participants’ two languages. Similarly, in the Go No-Go task, only one language is required for verbal responses in each block. It is

conceivable that effects associated with competition for selection were absent from processing underlying Go No-Go picture naming performance, thereby avoiding the switch cost asymmetry found in Experiment 1's Standard Picture Naming Task. Unfortunately, data from this task is not conclusive, partly due to the fact that the design for this experiment did not include a way to measure non-target language activation in the mixed language block. This can be investigated in a future study if activation of non-target language mixed block items can be definitively demonstrated in conjunction with a lack of asymmetric switch costs for non-balanced bilinguals. At this point, however, the lack of significant switch cost asymmetry in the mixed block of the Go No-Go task remains an interesting finding and suggests an important role for the requirement to name both languages.

Turning to the Semantic Categorization Task, analyses of switch costs demonstrated no significant interaction effect for language and type of trial (switch or non-switch). Combined with results from previously discussed tasks, this leaves the Experiment 1 Standard Picture Naming Task as the only task to demonstrate asymmetric switch costs to this point. Combined results are presented below in Table 24.

Table 24. Updated switch cost summary

Task Name (Experiment)	English Switch Cost (SD)	Korean Switch Cost (SD)
Standard Picture Naming (1)	62.25 ms (102.7)	111.62 ms (123.2)
Go No-Go Picture Naming (2)	23.4 ms, (142.2)	-21.1 ms (130.5)
Semantic Categorization (3)	18.2 ms (64.8)	20.1 ms (69.9)

Results from the Semantic Categorization Task are interesting in that they represent relatively novel findings in the area of switch cost research. To the author's knowledge, no previous bilingual language switch study has included a semantic categorization task with the same design as found in Experiment 3. It is also interesting in that the results run counter to expectations developed based on past switch cost research, which was composed of predominately production-centered naming tasks. To this point, results have primarily been judged in relation to Green's Inhibitory Control Model. However, as the IC Model was developed to account for bilingual language production, it is likely not the most appropriate model with which to compare receptive task results. In this regard, the BIA and BIA+ Models (Dijkstra & Van Heuven, 1998; Dijkstra & Van Heuven, 2002; Van Heuven, Dijkstra, & Granger, 1998) are likely more appropriate due to the fact that they focus specifically on bilingual visual word recognition. Unlike production-driven, top-down activation starting at the concept level (e.g., language production in the Inhibitory Control model), activation moves bottom-up in the BIA and BIA+ models. Critically, upon reading a word, individual features of letters receive activation first, and then each feature activates the letters that form words. The letters then activate the words that contain the specified letters (and letter combinations), with activation continuing upward to language tags, which represent every language for which a word was activated (e.g., both English and Spanish language tags would be activated for the letter string "PIANO"). This is a critical point that may partially explain the lack of switch cost asymmetry in the Semantic Categorization Task. As the BIA+ model is a language non-select model, inhibition of non-target items is still necessary. However, inhibition would only be necessary for non-target words that received activation from

lower levels. If, as the BIA+ model states, activation is sent upward to all letters, letter combinations, and words that share distinct features with the target word, it seems unlikely that English letters or letter combinations would activate Korean words (likewise for Korean characters activating English words) due to differences in scripts. (Note that cognates were intentionally excluded from the stimuli materials for this study.) Therefore, the BIA and BIA+ models provide a better explanation for the Semantic Categorization results, and likely represent a better model with which to evaluate results from the Lexical Decision Task.

A summary of findings to this point reveals switch cost asymmetry only for the Standard Picture Naming Task that requires verbal responses to both languages in the mixed block. The other two tasks, neither of which requires verbal responses, demonstrate no asymmetric switch costs. Based on findings so far, the Lexical Decision Task could be expected to demonstrate a lack of significant switch cost asymmetry in line with the Go No-Go Task and Semantic Categorization Task. The results from the Lexical Decision Task do follow this expectation in that no switch cost asymmetry exists in favor of the L2. However, data from the Lexical Decision Task are somewhat complicated, in that they actually demonstrate significant switch costs in the opposite direction (i.e., in favor of L1). Lexical Decision Task switch costs are presented below in a final summary of switch costs across the four language processing tasks.

Table 25. Final summary of switch costs

Task Name (Experiment)	English Switch Cost (SD)	Korean Switch Cost (SD)
Standard Picture Naming (1)	62.25 ms (102.7)	111.62 ms (123.2)
Go No-Go Picture Naming (2)	23.4 ms, (142.2)	-21.1 ms (130.5)
Semantic Categorization (3)	18.2 ms (64.8)	20.1 ms (69.9)
Lexical Decision (3)	33.7 ms (51.1)	18.6 ms (40.8)

The Lexical Decision Task requires only that participants determine if a string of letters is a word in either one of their two languages. No verbal response is required, and semantic processing requirements are minimal when compared to earlier tasks such as picture naming and semantic categorization tasks. It is therefore possible that the more automatic processing related to simple word reading and the lexical decision task is not sufficiently complex or time consuming to create the effects underlying asymmetric switch costs commonly found in production tasks. This is supported by a very recent study positing fundamentally different lexical processing between comprehension and production tasks (Gollan et al., 2011). It is therefore possible that the effects of more automatic processing associated with receptive tasks, reduced semantic processing requirements, and different scripts for the two languages used in this study combined to reverse the switch cost asymmetry demonstrated in the Lexical Decision task.

Overall, switch data from the four tasks included in this study demonstrate a pattern of results that appear to be influenced by task type, semantic load, and script of the first and second languages targeted in this study. While further research is needed,

these results highlight the potential effects of task design and experiment-related variables on switch cost findings.

10.3 Influence of individual differences on bilingual mix and switch processing

Individual differences in cognitive control and inhibitory control have been demonstrated in the literature, and the experience of early bilinguals in controlling attention to two languages has been shown to boost the development of executive control processes (Costa, Hernández, Costa-Faidella, Sebastián-Gallés, 2009; Bialystok, 1999, 2007; Kovacs & Mehler, 2009; Martin-Rhee & Bialystok, 2008; Prior and MacWhinney, 2010). Recent developments in the literature on bilingual language processing have implicated inhibition as a key cognitive mechanism supporting bilingual language use (e.g., Abutalebi, 2008; Hernández & Meschyan, 2006; Kroll, Bobb, Misra, & Guo, 2008), and a series of studies have found that highly proficient bilinguals outperform their monolingual counterparts on the antisaccade task (Bialystok, Craik, & Ryan, 2006) and the Simon task (Bialystok et al., 2004), as well as other tasks requiring inhibitory control (Colzato et al., 2008; Costa, Hernández, & Sebastián-Gallés, 2008; Festman, Rodriguez-Fornells, and Münte (2010).

Taken together, results from bilingual language studies suggest that individuals who demonstrate better inhibitory control skills may be cognitively better equipped to meet the demands of bilingual language processing, which makes this issue one of potentially great importance to the field of Second Language Acquisition. For these reasons, the potential relationship between general cognitive control and bilingual language switching was included as a focus in this study. The theoretical connection

between variations in non-linguistic cognitive control ability and the control required for language processing in mix-language environments appears strong. However, a direct link between general cognitive control ability measured by commonly used cognitive psychology-based tasks (e.g., the Simon Task and Anti-Saccade task) and control underlying language mix and switch performance remains elusive. As reported in Chapter 5, a pilot study found no significant correlations between mix and switch costs and two separate cognitive control tasks (Anti-saccade analogue task and a high/low switch task). This was not totally unexpected due to the relatively small number of participants involved; the N size for that task was 40. The failure to find a significant correlation between cognitive control ability and mix and switch cost performance was not limited to the pilot test however. In the current study, participants all completed the Simon Task, a commonly used measure of cognitive control. As was the case with the pilot study, no significant correlations were found between cognitive control ability and mix and switch cost performance on any of the four tasks included in this study. While the lack of significant correlations for Experiments 1 and 2 are perhaps not surprising due to the relatively small N sizes for each study (N sizes of 40 and 30, respectively), the Semantic Categorization Task and Lexical Decision Task both included more than 60 participants. However, no correlations between cognitive control ability and mix and switch performance neared significance. There are several possible explanations for the lack of significant cognitive control-related findings. First, it is possible that no relationship exists between non-linguistic task switching ability and the cognitive control bilinguals rely upon for language mix and switch-related processing. While possible, this seems unlikely based on the growing literature linking these abilities. The second possibility is

that the connection exists, but was not detected in this study due to either lack of sufficient sensitivity of the instruments used for these studies, possible range restriction within the participant sample, or a combination of both. Finally, the third, and most likely possibility, is that a combination of factors are likely impeding the discovery of the relationship between non-linguistic cognitive control ability and the control underlying mix and switch-related processing. Second language learning aptitude has been posited to be an interconnected complex of aptitudes and abilities (Robinson, 2001), and a direct, one-to-one relationship between linguistic and non-linguistic task switching might not exist. Again, the growing cognitive control literature does seem to suggest a relationship between cognitive control and language mix and switch-related processing. However, the results of the pilot test and current study make it very clear that a great deal of additional research will be necessary to isolate and identify it.

10.4 Conclusion

The primary purpose of this dissertation research was to investigate reported effects of language mixing and switching on processing by second language learners in an attempt to clarify the origin of the effects and better understand implications for Second Language Acquisition theory and aptitude testing. This study was composed of three separate experiments designed to investigate the mechanism(s) responsible for language selection as well as the source of mix and switch costs reported extensively in the bilingual language processing literature.

This research has identified critical questions that remain in the study of bilingual language mixing and switching and highlighted the importance of these questions to the field of Second Language Acquisition. A review of the relevant literature was presented, a series of experiments intended to further the understanding of mix and switch costs were detailed and expected results provided. Although the literature on this issue continues to grow, several critical questions remained. Therefore, this study was intended to provide new data capable of clarifying the following issues:

1. L2 advantage (and apparent L2 disadvantage) in mixed language environments
(Language mix effects)
2. Symmetry or asymmetry of language switch costs (Language switch effects)
3. Influence of individual differences on bilingual mix and switch processing

While the focus on individual differences in cognitive control failed to identify a significant relationship between non-linguistic cognitive control and mix and switch costs, the study was more successful with regard to the first two issues. Several past findings were replicated, such as generally faster reaction times for processing L1 items in single

block environments and faster L2 reaction times in mixed environments in the Standard Picture Naming production task. Several new findings were also reported, such as the lack of L2 advantage in mixed environments when verbal responses were only required for one of the bilinguals' two languages. This finding suggests that it may not be the mixed environment per se, but rather the requirement to respond in both languages that underlies the reaction time advantage commonly reported for L2 items in mixed language picture naming tasks. Also, no separate L1 disadvantage was found in the mixed block for any of the four tasks, outside of the well-established differential effect of repetition priming. This differential effect was confirmed by the novel addition of new pictures in the final block of the Standard Picture Naming Task. While reaction times for new pictures were significantly slower than new Korean pictures in the final block, reaction times for old (previously named) pictures did not differ significantly between Korean and English. That is, within the span of only three repetitions, slower L2 reaction times were sped up to the point where they matched L1 reaction times. This finding carries potentially critical implications for future mix and switch cost studies that repeat stimuli, as is common in this line of research. At the very least, the differential effect of repetition must be accounted for when designing future switch tasks.

Significant asymmetric switch costs favoring the L2 were demonstrated in only one of the four tasks (the Standard Picture Naming Task). This calls into question the generalizability of asymmetric switch costs, and focuses attention on task design variables in addition to learner variables (e.g., proficiency) that have been the major focus in past switch studies. Not only does the type of task (production vs. receptive)

potentially influence results, other variables such as script and semantic processing requirements may also play a role.

In summary, this project succeeded in presenting new data that has added to the understanding of mix and switch costs in second language processing. Further research is needed, however, to further explore these results.

Appendix A: Experiment 1 and 2 Mixed Block Presentation Order

List 1			List 2		
(Practice)	Set 1	EE	(Practice)	Set 1	KK
(Practice)	Set 2	KK	(Practice)	Set 2	EE
	Set 3	E		Set 3	K
	Set 4	K		Set 4	E
	Set 5	EE		Set 5	KK
	Set 6	KK		Set 6	EE
	Set 7	EE		Set 7	KK
	Set 8	KK		Set 8	EE
	Set 9	EEE		Set 9	KKK
	Set 10	KKK		Set 10	EEE
	Set 11	EE		Set 11	KK
	Set 12	KKK		Set 12	EEE
	Set 13	E		Set 13	K
	Set 14	K		Set 14	E
	Set 15	E		Set 15	K
	Set 16	K		Set 16	E
	Set 17	EEE		Set 17	KKK
	Set 18	KK		Set 18	EE
	Set 19	EE		Set 19	KK
	Set 20	KKK		Set 20	EEE
	Set 21	EE		Set 21	KK
	Set 22	KK		Set 22	EE
	Set 23	E		Set 23	K
	Set 24	K		Set 24	E
	Set 25	EE		Set 25	KK
	Set 26	KK		Set 26	EE
	Set 27	EEE		Set 27	KKK
	Set 28	KK		Set 28	EE

K = Korean picture

E = English picture

Appendix B: Experiment 1 and 2 Picture Stimuli List

List A.1

backpack
stroller
octopus
lighthouse
shovel
pirate
boat
rainbow
dentist
whale
bat
ladder
submarine
swing
~~tent*~~
bench
lion
toe
lamp
bomb
stairs
mirror
tear
rain
king
letter
baby

List A.2

firetruck
bathtub
zebra
hose
comb
walnut
strawberry
wallet
purse
slide
vacuum
nest
monkey
stove
towel
beard
thumb
ghost
clock
pool
shell
queen
bone
leaf
fish
road
car

List B.1

bird
washingmachine
pumpkin
teeth
snail
turkey
squirrel
spider
razor
scarf
arrow
pants
worm
shark
cross
elephant
nail
~~cheese*~~
pot
desert
rose
nurse
bridge
bag
bottle
paper
boy

List B.2

peas
diaper
cactus
peacock
kite
balloon
volcano
crab
wolf
tiger
drum
present
mouse
feather
waiter
camel
toilet
witch
map
rope
chain
plate
bone
soldier
church
city
girl

* Removed from Analyses

Appendix C: Lexical Decision Task English Words and NonWords

<u>English Words</u>	<u>English Words</u>	<u>English Nonwords</u>	<u>English Nonwords</u>
broom	lettuce	cine	drayly
wig	acorn	farl	verily
bell	slipper	bearn	berfin
goat	tire	chume	spaltrum
heel	fountain	buer	splondit
ghost	rabbit	mixe	scrupant
cake	lemon	prufe	conplute
hook	needle	grock	norrit
cow	candle	plend	splime
bomb	monkey	eran	luint
pig	ruler	pryme	kouter
stairs	feather	glar	bulgat
cloud	orange	fage	shintun
shirt	shower	mish	gruzer
bread	towel	prenk	trabit
bus	camel	helth	further
leaf	lion	larze	stadson
fish	mirror	chaz	caspin
leg	iron	serch	grigor
hair	mountain	blet	spaiding
road	flower	fald	skapan
car	finger	heast	nurthen
cowboy	music	ropent	pirskin
teapot	octopus	herbate	blorious
lizard	screwdriver	tweeth	delopran
diaper	mosquito	triner	denasive
scorpion	banana	cormon	soritan
magnet	butterfly	rebostr	beblital
scissors	umbrella	glizen	trotilent
turtle	elephant	pertrate	dacumert
airplane	potato	cropost	lanifold
balloon	radio	nekate	froctian

Appendix D: Lexical Decision Task Korean Words and NonWords

Korean Words

새
귀
삽
배
게
호랑이
손
쥐
통
성
총
칼
눈
뼈
코
책
어항
포도
하마
호박
기린
땅콩
벚꽃
거미
당근
사슴
여우
번개
잠금
양파
꿀벌
베개

Korean Words

무덤
수염
왕관
인형
버튼
사과
안경
소금
꼬리
경찰
지도
가슴
모자
지붕
다리
층의
구두
달걀
지점
상자
바위
의자
심장
다리
문자
아기
쓰레기
자전거
다람쥐
면도기
지팡이
달팽이

Korean Nonwords

삭
랭
곶
찰
긋
스버축
뿔
땀
삭
던
보
닌
훔
협
착
끔
끔말
달
읍
초
다
비
졸
환
곶
알
깎
순
착
랍
바
중
춘
을
학
분
족
도
팍
삭
힝
점
긴
혜
잔
금
쥘

Korean Nonwords

럼
절
자
롭
혜
괵
천
맥
를
팬
갈
븍
각
효
동
단
옹
곶
면
준
훔
괵
삭
헬
섬
족
업
곶
갑
핫
보
할
팍
곶
짜
확
요
툽
싫
익
걱
즉
침
영
건
병
반
시
험
적
변
으
학
을
힘
블
서
보
트
합
용
형
닉
석
경
면
축
정
궁
벽

Appendix E: Semantic Categorization Items

List A				List B			
<u>Occupations</u>	<u>직업</u>	<u>Eng NO</u>	<u>KOR NO</u>	<u>Occupations</u>	<u>직업</u>	<u>Eng NO</u>	<u>KOR NO</u>
Policeman	경찰관	dust	먼지	Farmer	농부	furniture	가구
Soldier	병사	house	집	Singer	가수	earthquake	지진
Pilot	조종사	swimsuit	수영복	Artist	예술가	trashcan	휴지통
Professor	교수	door	문	Doctor	의사	bottle	병의
Lawyer	변호사	flag	플래그	Nurse	간호사	balloon	풍선
<u>Body Parts</u>	<u>바디 부품</u>	<u>Eng NO</u>	<u>KOR NO</u>	<u>Body Parts</u>	<u>바디 부품</u>	<u>Eng NO</u>	<u>KOR NO</u>
Knee	무릎	lunch	점심	Ear	귀	smoke	연기
Nose	코	honey	꿀	Neck	목	playground	놀이터
Arm	팔	mountain	산	Leg	다리	desk	책상
Foot	발	jail	감옥	Finger	손가락	world	세계
Head	머리	money	자금	Hand	손	island	섬
<u>Weather</u>	<u>날씨</u>	<u>Eng NO</u>	<u>KOR NO</u>	<u>Weather</u>	<u>날씨</u>	<u>Eng NO</u>	<u>KOR NO</u>
Sunshine	햇살	bread	빵	Clouds	구름	door	문
Fog	안개	toothbrush	칫솔	Thunder	천둥	milk	우유
Flood	홍수	lock	잠금	Rain	비	poison	독
Lightning	번개	window	창문	Storm	폭풍	brain	두뇌
Snow	눈	magic	마법	Wind	바람	sidewalk	보도
<u>Family</u>	<u>가족</u>	<u>Eng NO</u>	<u>KOR NO</u>	<u>Family</u>	<u>가족</u>	<u>Eng NO</u>	<u>KOR NO</u>
Aunt	이모	bubble	거품	Grandmother	할머니	kite	연
Cousin	사촌	lake	호수	Uncle	삼촌	book	책
Sister	누나	ocean	바다	Daughter	딸	continent	대륙
Brother	오빠	volcano	화산	Father	아빠	soap	비누
Mother	엄마	stone	돌	Son	아들	parachute	낙하산

Appendix F: Semantic Categorization Mixed Block Stimuli List 1

Occupations

1	kn	가구
2	sey	policeman
3	en	flag
4	sky	예술가
5	sen	dust
6	sky	농부
7	ky	의사
8	kn	지진
9	sen	house
10	ey	professor
11	ey	lawyer
12	skn	풍선
13	sey	soldier
14	en	swimsuit
15	skn	병의
16	ky	간호사
17	sey	pilot
18	en	moon
19	sky	가수
20	kn	휴지통

Body Parts

21	en	jail
22	skn	연기
23	kn	세계
24	sey	knee
25	skn	놀이터
26	sey	nose
27	ey	arm

28	en	money
29	skn	책상
30	ky	다리
31	ky	손가락
32	sen	lunch
33	sky	귀
34	kn	섬
35	sen	honey
36	ey	foot
37	sky	목
38	ky	손
39	sen	mountain
40	ey	head

Weather

41	kn	문
42	sey	lightning
43	en	bread
44	sky	폭풍
45	sen	window
46	sky	바람
47	ky	천둥
48	kn	우유
49	sen	magic
50	ey	fog
51	ey	flood
52	skn	두뇌
53	sey	snow
54	en	toothbrush

55	skn	보도
56	ky	비
57	sey	sunshine
58	en	lock
59	sky	구름
60	kn	독

Family Members

61	en	volcano
62	skn	연
63	kn	비누
64	sey	aunt
65	skn	책
66	sey	cousin
67	ey	sister
68	en	stone
69	skn	대륙
70	ky	비누
71	ky	낙하산
72	sen	bubble
73	sky	할머니
74	kn	낙하산
75	sen	lake
76	ey	brother
77	sky	삼촌
78	ky	딸
79	sen	ocean
80	ey	mother

Appendix G: Semantic Categorization Mixed Block Stimuli List 2

Occupations

1	kn	풍선
2	sen	flag
3	en	dust
4	sky	의사
5	sen	swimsuit
6	sky	간호사
7	ky	예술가
8	kn	병의
9	sen	moon
10	ey	policeman
11	ey	soldier
12	skn	가구
13	sey	professor
14	en	house
15	skn	지진
16	ky	농부
17	sey	lawyer
18	ey	pilot
19	skn	휴지통
20	ky	가수

Body Parts

21	en	lunch
22	sky	다리
23	kn	연기
24	sey	arm
25	skn	세계
26	sey	foot
27	ey	knee

28	en	honey
29	skn	섬
30	ky	귀
31	ky	목
32	sen	jail
33	sky	손가락
34	kn	놀이터
35	sen	money
36	ey	nose
37	sky	손
38	kn	책상
39	sey	head
40	en	mountain

Weather

41	kn	두뇌
42	sen	bread
43	en	window
44	sky	천둥
45	sen	toothbrush
46	sky	비
47	ky	폭풍
48	kn	보도
49	sen	lock
50	ey	lightning
51	ey	snow
52	skn	문
53	sey	fog
54	en	magic

55	skn	우유
56	ky	바람
57	sey	flood
58	ey	sunshine
59	skn	독
60	ky	구름

Family Members

61	en	bubble
62	sky	비누
63	kn	연
64	sey	sister
65	skn	비누
66	sey	brother
67	ey	aunt
68	en	lake
69	skn	낙하산
70	ky	할머니
71	ky	삼촌
72	sen	volcano
73	sky	낙하산
74	kn	책
75	sen	stone
76	ey	cousin
77	sky	딸
78	kn	대륙
79	sey	mother
80	en	ocean

Appendix H: Lexical Robustness Categories

Categories

Countries

Clothing

Animals

Academic Majors

Colors

Fruits

Vegetables

Things with

Wheels

Musical

Instruments

Sports

Appendix I: Background Questionnaire

Thank you for your participation in this study. Please provide us with some background information.

1. What year were you born? 19_____.

Circle the appropriate answer for questions 2, 3, 4, and 5:

2. Gender: M F

3. Handedness: Right- Left- Mixed
 handed handed

**4. Are you a University Yes No
of Maryland student?**

4a. If yes, what is your major/ minor? _____/_____

4b. If yes, what year are you in? (Circle One) Undergraduate 1 2 3 4 4+
 Graduate 1 2 3 4 4+

5. How many years (total) have you lived in the United States? _____ Years.

5b. Have you ever lived in another English-speaking country? Yes No

If Yes, which country? _____

If Yes, for how many years? _____ Years.

6. Please provide information about your education history.

6a. How old were you when you first started to learn English? _____ Years old.

6b. Did you graduate from High School in Korea? Yes No

If you circled NO, in what country did you finish High School? _____

6c. Did you graduate from a University in Korea? Yes No

If YES, circle the appropriate **level** of degree completed: BA MA PhD

6d. Did you live or study in an English speaking country before the age of 13?

If Yes, Where? _____ For how long? _____ Years.

7. Please provide information about other foreign languages you know.

Language_____ How many years did you study this language? 1 2 3 4 5 5+

When (month/year to month/year) _____

Number of semesters completed 1) High School____ 2) University____ 3) Abroad____

Language_____ How many years did you study this language? 1 2 3 4 5 5+

When (month/year to month/ year) _____

Number of semesters completed in 1) High School____ 2) University____ 3) Abroad____

8. Please estimate your current ratio of English and Korean language usage.

8a. Overall Language Usage: _____ % English, _____ % Korean

(EXAMPLE: _____ 50 _____ % English, _____ 50 _____ % Korean)

8b. Language use at school: _____ % English, _____ % Korean

8c. Language use at home: _____ % English, _____ % Korean

8d. With friends: _____ % English, _____ % Korean

8e. Television, Internet: _____ % English, _____ % Korean

9. (Optional). Please provide scores and test dates for the following tests.

TOEFL _____ **GRE (VERBAL)** _____

Comments/questions about the study:

Thank you again for your participation in this study.

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