Contextual Differences in the Effect of Interference During Language Switching in Korean-English Bilingual Speakers

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in Korean-English bilingual speakers

by

Jungmee Yoon

A dissertation submitted to the Graduate Faculty in PhD. Program in Speech-Language-Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy,
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Jungmee Yoon

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Contextual differences in the effect of interference during language switching among Korean-English bilingual speakers

by

Jungmee Yoon

Co-Advisors: Dr. Loraine K. Obler & Dr. Klara Marton

Abstract

Bilingual speakers are assumed to activate two languages during language comprehension and production even when the input or output is in only one language. The parallel activation of both languages may result in competition between languages (e.g., Costa et al., 2006, Kroll, Bobb, & Wodniecka, 2006, La Heij, 2005). Earlier studies examined how the two languages are processed and controlled by mitigating interference during language selection (e.g., Abutalebi & Green, 2008; Marian & Spivey, 2003; Poulisse, 1999).

One way to study language control processes is to examine language-switching behaviors, a unique marker for these control processes (e.g., Bobb & Wodniecka, 2013). Although some earlier studies reported asymmetrical switch costs (i.e., larger switch cost from L2 to L1 than from L1 to L2), which were thought to reflect the role of inhibitory control in bilingual speech, more recent findings have been mixed, indicating that the nature of language control remains controversial (e.g., Calabria et al., 2012; Costa, Santesteban & Ivanova, 2006). Moreover, recent findings concerning bilingual language control imply that both language suppression and activation contribute to interference control during switching, leaving other
potential control processes largely under-investigated (compared to the notion of inhibitory control; e.g., Christoffels et al., 2007).

The current study aimed to understand how the control mechanism operates in specific switching contexts by (a) manipulating the degree of switch frequency, which stimulates a more or less competitive language switching context, and (b) contrasting language predominance, which signals a more L1 dominant versus L2 dominant switching context. Forty-four Korean-English bilinguals living in the United States performed a picture naming task in which the retrieval of words from each language varied according to the experimental manipulations.

The data were analyzed to explore possible effects of switch-frequency and language predominance. The bilingual speakers exhibited an overall naming advantage for English in both baseline and experimental conditions, independent of individual language proficiency. Moreover, a clear effect of switch frequency was seen (less frequent switches resulted in a greater local switch cost) while there was no effect of language predominance (similar patterns of switch costs were reported in both conditions). Particular task demands associated with levels of competition via switch frequency modulated levels of interference, resulting in different degrees of local vs. global switch costs within bilingual individuals. In conclusion, the current findings suggest that the language environment (immersion context), as well as the experimental task conditions varying by switch frequency have an effect on the bilingual language control mechanism.
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Chapter 1. Introduction

Bilingual speakers can activate two languages in parallel even when they are comprehending or producing linguistic information in only one language. The parallel activation of both languages has motivated earlier studies to examine the neurological and cognitive aspects of bilingual language processing, demonstrating how the two languages are processed and controlled (e.g., Marian & Spivey, 2003; Poulisse, 1999). Bilingual speakers have been assumed to develop language control processes in order to manage their two languages by mitigating interference during language selection (e.g., Abutalebi & Green, 2008). One way to study language control processes is to examine language switching behaviors, a unique marker for these control processes (e.g., Bobb & Wodniecka, 2013). Although certain aspects shared between the domain-general and language control processes are suggested in the literature, the nature of language control remains controversial (e.g., Calabria et al., 2012; Costa, Santesteban & Ivanova, 2006). The current study investigates the effects of interference on bilingual language switching, in particular, the extent to which the language control processes are specific to language or are mediated by the domain-general control processes.

1.1. Overview of bilingual speech production

According to widely agreed-upon models of monolingual speech production (i.e., Levelt, Roelofs, & Meyer, 1999; see also Dell, 1986; Caramazza, 1997), there are necessary processes by which the target representations for lexical selection can be successfully accomplished. Semantic activation at the conceptual level cascades down to the lexical level, resulting in activation of semantically related lexical representations. At the lexical level, additional representations (or lexical nodes) are simultaneously activated along with the target. Thus, lexical selection is required for identifying and choosing the most highly activated lexical
representation among its competitors. Following the retrieval process of the lemma (or the lexical representation), encoding processes of morphological and phonological representations accompany the selected lexical representation in order to prepare for articulation. It seems that timely and sufficient activation of lexical representations at each stage may be obligatory during speech planning in monolingual speakers (e.g., Levelt, 2001).

Compared to monolingual speech production, the speech planning mechanism for bilingual speakers is more complicated (e.g., Costa et al., 2006, Kroll, Bobb, & Wodniecka, 2006, La Heij, 2005). A fundamental assumption behind the complexity of bilingual speech production is the parallel activation of lexical representations from two languages during speech planning. In bilingual cases, speech planning encompasses two initial stages similar to those observed in monolingual speakers: 1) the selection of semantic or conceptual representations, and 2) the selection of lexical representations from a set of activated lexical items (e.g., Schriefers et al., 1990; Peterson & Savoy, 1998). The latter stage of the selection process, however, differs between monolingual and bilingual individuals in that two lexical representations (i.e., a word in the target language and its translation equivalent from the other language) are concurrently activated to compete for selection in bilingual individuals, while only one final candidate is strongly activated in monolingual individuals. The parallel activation of the two languages may result in competition between languages. This is particularly true between the two highly activated lexical representations corresponding to the target concept, even when a bilingual speaker is asked to produce lexical items only in one language (e.g., Costa, 2005).

Accordingly, the lexical selection process in bilingual speakers should be differentiated from that of monolingual speakers. Of particular interest is the manner of language selection, which involves language control to resist interference between the two languages’
representations. Our understanding of language control in general suggests that selection processes may operate to control and resolve the competition during lexical retrieval (e.g., Green, 1998; Meuter & Allport, 1999; Costa et al., 2006). In the following chapter, I will review previous literature to address pertinent questions related to the language control mechanism in bilingual speech production.
Chapter 2. Literature review

2.1. The language control mechanism in bilingual speech production

2.1.1. Language competition during bilingual lexical retrieval

The basic assumption about bilingual lexical retrieval is that the process of lexical access and selection is hindered by cross-language competition while the two languages are co-activated. As the co-activated languages compete for selection, the retrieval time required to select the target lexical item is increased by the levels of activation of the nontarget language as well as the target language. Often, slower lexical retrieval performance in bilingual speakers, relative to monolingual peers, has been taken to support such a language selection by competition hypothesis.

2.1.2. The nature of bilingual language control mechanism

Researchers have attempted to understand the nature of the control mechanism that functions to resolve the language competition in bilingual speech production (e.g., Abutalebi, 2008; Lee & Williams, 2001). A fundamental theoretical question about the language control mechanism that underlies lexical selection is whether it is domain-specific (language-specific) or domain-general (e.g., Abutalebi et al., 2011; Costa & Santesteban, 2004; Hoshino & Kroll, 2008; Weissberger et al., 2012). A general consensus has emerged that a domain-general control mechanism for language competition during bilingual lexical retrieval is analogous to the (nonlinguistic) cognitive control processes (e.g., Abutalebi & Green, 2008; Costa et al., 2009; De Baene et al., 2015). This also invites the questions about the potential relationship between the cognitive and language domains.
The Inhibitory Control hypothesis (IC; Green, 1998) has been proposed to explain the nature of bilingual language control, assuming a link between the cognitive and language domains. According to the IC account, a domain-general control mechanism, which operates as a cognitive control to inhibit irrelevant information, may also mediate competition by reactively suppressing the (activated) nontarget language schema and thus the lexical representation in the nontarget language. One way to examine this control mechanism in bilingual speakers involves assessing the consequences of behavioral adaptation in executive control, or more specifically, the ability to resist non-linguistic interference (e.g., Bialystok, 2001; Bialystok, Craik, Klein, & Viswanathan, 2004). Non-linguistic (cognitive) executive function tasks have been employed to assess whether bilingual speakers, relative to their monolingual peers, have developed advanced cognitive functions rooted in their practice of language regulation (e.g., Prior & Gollan, 2011; 2013; Prior & MacWhinney, 2010; Hilchey & Klein, 2011 for a review of bilingual advantage, but see also Paap & Greenberg, 2013). Evidence for the idea of a bilingual cognitive advantage, which is not within the scope of the current study, appears to support the interplay between language control and cognitive control processes. Yet, the nature of the language control mechanism and the extent to which the control processes are shared across domains remain controversial based on mixed evidence for and against the inhibitory control hypothesis.

The comparison of performance across cognitive- and language-control domains is both a complementary and direct approach to understanding the link between cognitive control and language control. Language switching is of particular interest because frequent language switching (e.g., code mixing) reflects presence of the language control mechanism, which enables spontaneous, error-free switching behavior (Poulisse and Bongaerts, 1994; Poulisse, 1999; Gollan & Ferreira, 2009). This fundamental characteristic of bilingual speech, language
switching, is considered to reflect flexible cognitive abilities (e.g., resistance to interference) on a daily basis in bilingual speakers (e.g., Gollan & Ferreira, 2009). Motivated by the unique phenomenon of bilingual code mixing and the theoretical assumption of a link across domains, prior studies on bilingualism have addressed whether the control processes that have been widely reported to operate during task switching are analogous to those for language switching (e.g., Prior & Gollan, 2011; Von Studnitz & Green, 1997; Weissberger et al., 2012). In the next sections, I will discuss a set of empirical evidence for language control based on language switching performance.

2.2. Language switching studies in the literature

As briefly stated in section 2.1.2., current understanding of bilingual language control has been limited to the effects of bilingualism on cognitive control processes (e.g., Costa et al., 2009; Hilchey & Klein, 2011), especially those underpinning effective language switching performance (e.g., Abutalebi et al., 2011; Blanco-Elorrieta & Pylkkänen, 2015; Green & Abutalebi, 2013). Both theoretical and empirical perspectives of the control processes underlying language switching further motivate researchers to study the processes specific to language switching in terms of overlapping versus non-overlapping aspects of the control processes across domains. Thus, it is crucial to investigate the underlying processes by considering factors that contribute to nonlinguistic task switching in the domain of language switching.

In the following sections, I will first describe the common methodology, i.e., a switching paradigm, and its measures that have been utilized to understand the control processes associated with switching across domains. Then, I will summarize the findings of previous language switching studies which reported evidence for language control, considering the theoretical and methodological issues relevant for our understanding of bilingual language-switching behavior.).
First, I will introduce empirical data that support the notion of general control processes; then I will report the data that support language-specific control processes.

2.2.1. A cued switching paradigm

In the task switching literature, an efficient switching ability is often considered a marker for cognitive control, which enables individuals to flexibly switch back and forth between task sets or mental sets. According to the literature, competition between different task sets or mental sets may increase levels of interference during switching; interference should be resolved in order for individuals to perform flexible switching or efficient adaptation to changing situations (Monsell, 2003). One commonly used methodology for assessing the ability to resist interference involves a cued switching paradigm in which participants are asked to perform in both a single-task condition and a mixed-task condition (e.g., Monsell, Yeung & Azuma, 2000). In the mixed condition of a switching paradigm, participants switch back and forth between tasks, and their performance is typically slower and/or less accurate on switch trials than on non-switch (stay) trials.

In the bilingual literature, a cued language-switching paradigm has also been utilized to further examine control processes (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999). In the language switching paradigm, participants are asked to name a picture either in the monolingual language condition or the mixed-language condition. Participants are asked to name a word in the target language according to a given language cue in all trials of the mixed-language condition, consisting of both stay and switch trials. Performance decrease is expected in switch trials of the mixed language block (i.e., when the target language is different from that of the previous trial), whereas a speed advantage or little change in speed is expected in stay trials (i.e., as an effect of facilitation or priming when the same language is repeated).
2.2.2. A hallmark for control processes during switching: switch costs

Effects of interference on switching performance often vary across the switching conditions or trials, and how bilingual speakers resolve the interference or avoid intrusion errors from the non-target language lies at the center of interest in the literature. These phenomena can be measured by performance change resulting from switching in the mixed condition, commonly known as the (local) switch cost, which is typically computed by comparing performance on switch trials to performance on stay trials in a mixed-task condition (e.g., Bryck & Mayr, 2008; Kiesel et al., 2010). The switch cost, i.e., the increased time required to switch, indicates increased processing demand, presumably reflecting the control processes that would permit the observed flexibility for successful switching behaviors (Monsell, 2003). According to the notion of Task set inertia (Allport et al., 1994), one of the primary sources of switch costs has been attributed to proactive task interference from divergent stimulus-response mapping between two tasks. When a new task set is assigned to be the target set, the previously relevant task set, which had received extra activation, becomes irrelevant. Thus, the interference resulting from the high activation of the previous target task set that occurs with the current one should be resolved. Doing so will overcome either the residual activation of a previously used task set or the active suppression of a previously competing one (e.g., Allport et al., 1994; Kiesel et al., 2010; Monsell, Yeung, & Azuma, 2000).

Of particular interest is asymmetry in switch costs between a pair of tasks with unequal strength (e.g., Allport et al., 1994; Meuter & Allport, 1999). In the domain of bilingual language switching, an asymmetrical pattern can sometimes be seen for switch costs (for similar results, see Costa & Santesteban, 2004; Finkbeiner, Almeida, Janssen, & Caramazza, 2006; Philipp, Gade, & Koch, 2007). That is, a significantly larger cost is observed when switching to a more
dominant L1 (or a difficult task) than when switching to a less dominant L2 (or an easier task). The asymmetrical switch costs may result from baseline activation of each language (or task set) that should inherently differ by language dominance (analogous to task strength or difficulty), affecting both the residual activation of a previously used language and the inhibition of a competing language set. One prominent interpretation of task switching performance assumes differential persistence of task set inhibition versus activation as a result of varying degrees of interference between the tasks (e.g., Kiesel et al., 2010). Thus, the language switch costs can also be interpreted with more emphasis on the relationship between the strength of both representation and interference, and inequality in control biases for language and response selections.

2.2.3. Issues relating to use of terminology

Inconsistent use of terminology when referring to the control mechanisms and a broad definition of the term inhibition have created problems when experimental results are interpreted. In the cognitive psychology literature, inhibition-related functions all seem to require a certain degree of executive control. Thus, some researchers regularly conceptualize inhibition as a unitary construct of cognitive control. The different types of inhibitory control seem to be closely related, but they are distinct enough to be separable in an analysis with latent variables (Friedman & Miyake, 2004). It is not clear the extent to which inhibition-related functions can be accounted for by the same underlying cognitive construct while they are correlated with each other. MacLeod and colleagues (2003) argued that inhibition and interference (and the concepts behind the terms) should not be used interchangeably, or treated in the same manner. That is, the term interference should describe a phenomenon that explains the behavioral cost at a response level (as an effect), whereas the term inhibition (or inhibitory control) implies an underlying
mechanism involving active suppression at the cognitive level (MacLeod et al., 2003).

Inconsistent terminology makes it difficult to interpret results and obfuscates our understanding of bilingual phenomena. For example, the factors that may account for differential effects of interference on language switching, e.g., task demands related to activation strengths of each language representation, have not been studied much since language switching performance has been mainly interpreted through the lens of inhibition (Declerck & Phillipp, 2015).

Note that there are several ways to conceptualize and classify the inhibition-related functions in the cognitive literature (e.g., Harnishfeger, 1995; Nigg, 2000; Wilson & Kipp, 1998). According to Friedman & Miyake (2004), the major inhibition-related processes are 1) prepotent response inhibition, 2) resistance to distractor interference, and 3) resistance to proactive interference. Of the three inhibition-related functions, the resistance to distractor interference, which reflects control abilities to suppress in the presence of stimulus competition (Nigg, 2000), seems most relevant to language competition during bilingual language production. The resistance to interference, also known as response-distractor inhibition, has also been reported to be reflected by switch costs when the distracting information is simultaneously competing with the target information (Friedman & Miyake, 2004). In the current study, the term interference will be used to describe a source of any behavioral costs during bilingual language switching. Interference control will imply the language control mechanism which suppresses irrelevant and distracting information due to language competition1. Furthermore, I will also consider how language-switching responses can be hindered versus facilitated by the level of interference, and will explore alternative aspects of the control processes aside from inhibition.

---

1 I will use the term interference in the current study unless previous studies clearly articulated the term inhibition for the particular control process.
2.3. Evidence from the switching literature: language switching performance

The notion of switch cost, as a distinctive marker of interference control during switching, has theoretical implications for domain-general aspects of language control (e.g., Meuter & Allport, 1999; Linck, Schwieter, & Sunderman, 2012). A set of studies has reported comparable patterns of switching across domains, based on switch cost findings in both cognitive task switching and language switching (e.g., Linck et al., 2012; see also Weissberger et al., 2012). However, not every study reported findings consistent with the aforementioned results, suggesting that there are both overlapping and non-overlapping aspects of switching performance between cognitive (non-linguistic) and linguistic domains (e.g., Calabria et al., 2012). It is worth reviewing the language switching data in detail to understand the nature of the language control processes during language switching.

I will briefly summarize the first set of empirical findings that indicate the similarities in control processes for both language switching and task switching, and then review another set of data that has implications for the language control processes specific to language switching. The critical evaluation of these mixed findings will lead to further discussion of different sources of asymmetrical switch costs, or effects of interference, pertaining to advancing our current understanding of the control processes for language selection.

2.3.1. Evidence for domain-general aspects of language control

An important consideration that could shed light on bilingual language control involves the aforementioned switch cost asymmetry, which is arguably caused by the different degrees to which the control processes are utilized between languages (e.g., Meuter & Allport, 1999). That is, switch costs differ according to the direction of the switch; greater costs are found when
switching from a less dominant language (L2) to a more dominant language (L1) than vice versa. The counterintuitive findings on asymmetry during language switching have been taken as evidence for the domain-general inhibitory control mechanism (Green, 1998). According to the account, the control mechanism reactively suppresses the (activated) non-target language schema and lexical representation in the non-target language to mediate interference during bilingual language production in general (Meuter & Allport, 1999; Colzato et al., 2008; Costa, Santesteban, & Ivanova; 2006; Kroll, Bobb, Misra, & Guo, 2008). Studies on language switching have reported overlapping aspects of language control and cognitive control based on their behavioral and online measures in asymmetry, i.e., greater switch costs or greater negativity in ERP data for the switching direction from a less dominant language (L2) to a more dominant language (L1) (e.g., Christoffels, Firk, & Schiller, 2007; Kroll et al., 2008; Misra, Guo, Bobb, & Kroll, 2012; Verhoef, Roelofs, & Chwilla, 2009). Also evident in fMRI data, greater cortical activation is assumed to reflect more effortful processing in the responses from L2 to L1 than from L1 to L2 (e.g., Rodriguez-Fornells, De Diego Balaguer, & Münte, 2006).

In addition, robust evidence for the shared control processes comes from direct comparisons of behavioral performance and/or the neural correlates between task switching and language switching tasks (e.g., Abutalebi et al., 2012; Prior & MacWhinney, 2010; Prior & Gollan, 2011; Weissberger et al., 2012). For example, similar or overlapping neural substrates were recruited to resolve interference during switching in both non-linguistic and linguistic switching tasks (e.g., Abutalebi et al., 2012; Weissberger et al., 2012). Based on the switch cost measures, a significant correlation observed between task switching and language switching abilities may also reflect the domain-general control mechanism (e.g., Prior & Gollan, 2011). Furthermore, the relationship between the language and cognitive domains was particularly
strong for one group of bilingual speakers, who exhibited more flexible language use between the two structurally similar languages (i.e., Spanish-English bilingual group) relative to the other group (i.e., Mandarin-English bilingual group), indicating that language usage along with the language pair may contribute to bilingual language control.

Some factors related to individual differences in language use seem crucial to understanding the domain-general aspect of language control during switching. Bilingual mental lexicons are controlled by this dominance-related inhibition, that is, there is more control for the language with the higher baseline activation (Costa & Santesteban, 2004; Tarlowski, Wodniecka, & Marzecová, 2013). Accordingly, the asymmetry in switch costs should be clearly observed due to the noticeable imbalance between the two languages among dominant bilingual speakers, or second language learners who demonstrate relatively large differences in approximate measures of language dominance and/or proficiency. The expected asymmetry in switch costs was easily produced by different levels of language imbalance in a computational model (Filippi, Karaminis, & Thomas, 2013). Note that individual language dominance is often seen in overall naming speed, presumably in line with language proficiency levels. Many studies found faster overall naming in L1 than in L2 as a reason for the asymmetrical switch costs that result from the higher baseline activation in L1 than L2 (e.g., Declerck, Koch, & Philipp, 2012; Linck et al., 2012; Macizo et al., 2012). This finding confirms the logic behind the dominance-related interpretation related to the baseline activation of the languages, which presumably reflect the strength of language representation by individual language dominance (e.g., Meuter & Allport, 1999; Filippi, Karaminis, & Thomas, 2014).

It is worth mentioning that the domain-general aspect of language control is not restricted to the switching performance on switch trials. According to Christoffels and colleagues (2007),
one viewpoint that complements the evidence of asymmetry in local switch costs states that the
global language control mechanism might operate to inhibit a whole language in a more
sustained way across trials. A global language control (or the sustained nature of the control
processes) can be distinguished from a local or trial-by-trial reactive feature of inhibitory control
(e.g., Ma et al., 2015). Ma, Li, and Guo (2015) elucidate the dissociable aspects of the two
language control processes by using different terms: reactive (inhibitory) control versus
proactive control during language selection. In contrast to reactive control, proactive control is
assumed to deliberately modulate the activation levels of target lexical items in the two
languages. One way to measure this control mechanism is to utilize a so-called global switch cost
or mixing cost (i.e., speed difference between the single block and the stay trials of the mixed
block), which is considered an index for the functioning of higher-level executive control
processes (Cepeda et al., 2001).

Bilingual speakers exhibit asymmetry in the global switch costs as the speed advantage
for the dominant language (or the typical proficiency effect) that is often seen in a single
language block disappears when the two languages are mixed. That is, a greater mixing cost for
the more dominant language than for the less dominant language has been reported in language
switching studies (Christoffels et al., 2007; Costa & Santesteban, 2004; Philipp et al., 2007; Prior
& Gollan, 2011; Verhoef et al., 2009). By virtue of the more sustained, global (inhibitory)
control processes, a global slowing of the dominant language in the mixed condition might
significantly contribute to the asymmetry in mixing costs (e.g., Misra, Guo, Bobb, & Kroll,
2012). The sustained nature of language control at the language-schema level presumably
coexists with the local inhibitory control processes during a given trial (Green, 1998).
Asymmetry in both local and global switch costs has been noted as a hallmark of language control in a growing body of studies (e.g., Christoffels et al., 2007).

I have so far addressed certain aspects of a domain-general cognitive control mechanism that explains a bilingual’s ability to select a language by avoiding interference from the other language. The similar pattern of switching performance across domains suggests the domain-general nature of language control. Despite the consensus of the overlapping aspect of cognitive control crucial for both language selection and task selection, divergent patterns of switching across different markers for control have made it difficult to draw conclusions concerning the nature of language control (e.g., Meuter & Allport, 1999; Costa & Santesteban, 2004; Verhoef, Roelofs, & Chwilla, 2009). The pattern of global switch costs is not always parallel to that of local switch costs during language switching (e.g., Christoffels et al., 2007; Green & Abutalebi, 2013; Misra et al., 2013; Prior & Gollan, 2011). Asymmetrical switch costs have been attributed to relative proficiency differences between the two languages; however, the relationship between asymmetry and proficiency is not clear due to the mixed results. Accordingly, whether language control is (completely) subsidiary to the domain-general cognitive control mechanism remains a question (e.g., Abutalebi et al., 2008). The idea that the switch cost asymmetry results from individual differences in language dominance cannot be solely attributed to the domain-general mechanism of inhibitory control. In the following section, I discuss evidence for language-specific aspects of bilingual language control.

2.3.2. Evidence for language-specific aspects of language control

Several alternative hypotheses have been suggested to challenge or reconcile with the domain-general reactive inhibition (e.g., Christoffels et al., 2007; Costa, Santesteban, & Ivanova, 2006; Green & Abutalebi, 2013; Hilchey & Klein, 2011), indicating that the language control
mechanism can be as dynamic as bilingualism itself. The mixed findings can be explained by language-specific aspects of language control. For example, Costa and Sanesteban (2004) observed the switch cost asymmetry for dominant bilinguals, but not for balanced bilinguals, suggesting a functional shift in the nature of the control mechanism related to language competition. Development of control processes specific to language (i.e., language-specific selection process) could result from bilingual speakers’ continuous and therefore advanced use of the control processes over their two languages (Costa & Sanesteban, 2004). In the current section, I will address evidence for language-specific aspects of control that play complementary roles in bilingual language control.

Note that both asymmetry and symmetry have been reported within the same group of bilingual speakers, whether balanced or dominant (e.g., Finkbeiner et al., 2006; Costa, Sanesteban, & Ivanova, 2006; Verhoef, Roelofs, & Chwilla, 2009). Philipp, Gade, and Koch (2007) have also demonstrated somewhat contrasting effects of relative proficiency difference on asymmetry, based on lack of the proficiency effect on asymmetry (i.e., when comparing L1-L2, L1-L3, & L2-L3 pairs with different levels of proficiency). Diverse findings such as these suggest that individual language proficiency itself cannot account for the asymmetry versus symmetry in switch costs.

Alternatively, it is possible that language control is partially subsidiary to cognitive control, involving control processes (e.g., Calabria et al., 2012; Costa & Sanesteban, 2004). In neuroimaging data, Abutalebi and his colleagues (2008) demonstrate neural recruitment of non-overlapping areas that is specific to language control in addition to shared areas across domains during language switching. A set of psycholinguistic evidence supports the claim that there are some control processes unique to language (e.g., Calabria et al., 2012; Prior and Gollan, 2013, &
Weissberger et al., 2012). For example, recent observation of highly proficient bilingual speakers reveals qualitative differences between nonlinguistic and linguistic switching abilities (Calabria et al., 2012). In their study, the authors have reported different patterns of switching performance (e.g., asymmetry vs. symmetry) and a lack of correlation between task switching and language switching in terms of the magnitude of the switch costs. Furthermore, the differential effects of age-related decline on switch costs differ between domains, indicating that language control, not task control, could be relatively less influenced by advancing age (Prior & Gollan, 2013). These findings have challenged the claim of complete overlap between cognitive and language control, indicating some degree of difference between the two types of control processes.

A distinctive feature of language control reported via various switching paradigms relates to effects of different linguistic tasks on control demands during language switching (e.g., Gollan et al., 2014). For example, Gambi and Hartsuiker (2016) found an effect of interlocutors’ language selection on language switchers’ switching in a joint switching paradigm, indicating switch costs from comprehension to production as evidence for language-specific aspects of language control. An interesting note from the authors, based on their findings of cross-modality switch costs, was that not only top-down (inhibition) control but also bottom-up activation may contribute to bilingual language selection and control in determining naming latencies (Gambi & Hartsuiker, 2016).

Another study motivated by the assumption that bilingual speakers voluntarily switch between languages during spontaneous conversation was conducted by Gollan and Ferreira (2009). The authors investigated whether voluntary and mandatory switching tap different processing demands. Dominant bilingual participants who were asked to “voluntarily switch” between languages demonstrated neither asymmetry nor a language dominance effect,
suggesting that a relatively small amount of language control can be applied to the dominant language in natural conversation. Of note was that under the voluntary instruction, most bilingual speakers remain in one language rather than switching frequently back and forth, implying that as a rule, bilingual speakers select a matrix language (Gollan & Ferreira, 2009). This highlights the task effect on language switching such that bilingual speakers may want to avoid any costs associated with keeping both languages at a high level of activation, particularly in a naturally occurring switching context.

Although some unique aspects of language control have been proposed, to what extent these aspects can be language-specific versus general has not been fully investigated. Thus, we can assume that inhibitory control may still be necessary but not solely sufficient for language control in a given situation. Different sources of switch costs, e.g., a more persistent activation of L2 relative to L1 from the previous trial toward the current trial), contribute to varying effects of interference on the two languages spoken by bilingual individuals (Bobb & Wodniecka, 2013). Based on their review of the mixed findings, Bobb and Wodniecka (2013) argue that the effects of interference on bilingual language switching can be modulated by factors related to participants (e.g., proficiency or dominance) as well as task manipulations. It is important to understand theoretical and methodological factors, some derived from the task switching domain and others specific to the language switching domain. Thus, the next section will evaluate pertinent issues related to theoretical and methodological aspects that provide information regarding bilingual language control. A thorough understanding of the factors that seem to influence the results motivates the current study to address additional factors contributing to the language control.
2.4. Critical evaluation of the mixed findings on bilingual language switching

There are many variables that seem to modulate the degree of language control, contributing to the mixed findings in the bilingual literature. Switching direction is one of these variables that modulate the degree of interference between languages, as reflected by the magnitude of switch costs. In the literature, the difference in switch costs between the switching directions often relates to language dominance; L1 is typically assumed to be more activated than L2 by frequency of daily language usage within an individual. Measuring levels of baseline language activation can provide meaningful information; yet, baseline activation can be also modulated by task-related factors in a given language context (Bobb & Wodniecka, 2013). Therefore, questions about relative contribution of language activation by language dominance to language control across switching contexts remain open.

The manner of language control may differ across switching tasks. The target language can be activated to a higher degree than the nontarget language via language control (e.g., by globally inhibiting the latter), and the lexical candidate in the target language is then selected with ease at the lemma level. Language control may begin the operation at an earlier point in the selection process and continue the operation throughout the process; for example, global switch costs are also seen to reflect language activation and control. The findings on global switch costs have implications not just for the locus but also for the manner of language control (e.g., Christoffels et al., 2007; Verhoef, Roelofs, & Chwilla, 2009). Relating to the manner of language control, the reactive nature of inhibitory control may not always exclusively operate as the language control mechanism. Rather, bilingual speakers proactively control interference between their languages, and language contexts are implicated to modulate degree of interference during
language selection and switching. The switching contexts in which we could see evidence for different manner of language control will be further discussed below.

Note also that the levels of language dominance, as reflected by levels of baseline activation of the two languages, cannot solely determine the extent of language control that are modulated. For example, similar overall naming latency for both L1 and L2 was observed with both symmetry (e.g., Calabria et al., 2011; Fink & Goldrick, 2015) and asymmetry (e.g., Declerck et al., 2013; Filippi, Karaminis, & Thomas, 2014), and faster L2 naming than L1 was observed with both symmetry (e.g., Gollan & Ferreira, 2009; Verhoef et al., 2010) and asymmetry (e.g., Costa & Santesteban, 2004; Verhoef et al., 2010). Those studies have employed experimental manipulations to vary control demands and/or to necessitate different types of language control. Thus it seems that task variables can contribute to how bilingual speakers resolve interference during switching. One may ask whether even the baseline activation of each language can be affected by task demands or task-related factors that influence control demands during switching.

Motivated by the effect of task preparation on task switching (e.g., Vandierendonck et al., 2010), a recent study by Ma and colleagues (2015) demonstrates the differing effects of task demands on the degree of control by manipulating timing. The experimental variables consist of three measures of time interval: the time interval between a language cue presented before the stimulus and the stimulus ( Cue-Stimulus Interval; CSI), the time interval between a stimulus and the language cue presented after it ( Stimulus-Cue Interval; SCI), and the response cue interval, that is, the time between the response to the previous trial and the language cue in the condition where the language cue precedes the stimulus ( Response-Cue Interval; RCI).
The authors report several findings of note: 1) increased CSI provides sufficient time to activate the target language based on a cue, and it reduces the need for language control, resulting in reduced global switch costs; 2) increased RCI leads to divergent findings regarding switch costs, i.e., asymmetry in global switch costs but reversed asymmetry in local switch costs, suggesting that the longer post-response interval makes proactive control processes sensitive to language dominance, but reduces its sensitivity to the dominant language by overcoming the reactive control processes; and 3) reversed asymmetry in local switch costs with the manipulation of SCIs, which also alters the language dominance effect with the preparation time for activation of the two target languages by providing a stimulus before a language cue. Based on the differential effects of preparation time on language switching, these results suggest that bilingual participants might strategically boost activation of the target lexical item in L2 when a sufficient amount of time is given for equalization with its translation equivalent in L1 (Ma et al., 2015).

Strengthening of language set activation by increasing preparation intervals can reduce the need for language control. Note that several other studies examined the effect of preparation time regarding language control processes with a focus on whether the asymmetry in switch costs can be reduced with longer preparation time (e.g., Costa & Santesteban, 2004; Philipp et al., 2007; Verhoef, Roelofs, & Chwilla, 2009). Even though the results of the effects of preparation time on the (local) switch costs are mixed across studies due to variation in procedures and participant profiles, overall findings across studies seem to converge on the language control processes that can be dynamically modulated by task demands. Efficient language and lexical selection can be accounted for by lowering demands for control when the task demands create particular language contexts. The switching performance across varying
contexts provides evidence for the dynamics of language control, e.g., different control processes as measured by different markers as a function of timing manipulations.

Switching contexts in experimental studies may result in differential effects of interference on switching performance; indeed, the task switching literature suggests that switching contexts as a function of switch frequency would predict differential effects of interference as the control demands may vary (e.g., Nessler, Friedman, & Johnson, 2012). For example, Nessler et al. (2012) examine the effect of switch frequency, finding the opposite patterns of both local and global switch costs between frequent and infrequent switching contexts. This may suggest that task sets are maintained at a higher baseline activation level by increased demands for task-set updating when switch frequency is high. In a similar vein, De Baene and Brass (2013) investigate that such contextual differences by switch frequency result in different preparation-related cognitive control areas of the brain. In the language switching domain, very few studies have also documented effects of switching contexts by varying demands of switching. Of particular interest, though, was that Gollan and Ferreira (2009) unexpectedly found stay costs when the voluntary switching was restricted by requiring switching half the time, and that their bilingual participants set a matrix language to facilitate the naming performance and to reduce the voluntary-switching costs in the switch context. This particular finding could imply that participants strategically switch versus stay by utilizing and/or adapting a series of control processes, such as planning and monitoring in a given switching condition, as the authors speculated (Gollan & Ferreira, 2009). In addition to theoretical relevance of language control, it is crucial to understand how the effect of language dominance at the individual level may interact with the task effects (e.g., frequent vs. infrequent switching contexts) on interference control during language switching, as will be addressed in my study.
The literature makes clear that bilingual speakers can adapt their control processes depending on switching contexts with varying demands, such as preparation time for task-relevant activation or setting a matrix language in voluntary switching contexts. One question left unanswered is how bilingual speakers would adapt the control processes depending on switching contexts by varying degrees of language activation, e.g., as a function of switch frequency. Thus, the current study will examine how switching contexts can vary by switch frequency, another task-related variable that has been presumed to modulate the task-set strength and the level of interference during switching (Nessler et al., 2012). Moreover, language-specific loads will vary by language predominance, which is expected to provide a relevant context for bilingual individuals according to their language dominance at an individual level. Therefore, I aim to clarify the nature of the language control mechanism during language switching among highly proficient bilingual speakers by examining specific effects of task set activation that have been reported to affect interference control processes during task-switching (i.e., by varying switch frequency and strengthening task set activation).
Chapter 3. The Current Study

3.1. Outline of the Current Study

3.1.1. Rationale for the study

Based on the literature review, there is general agreement that bilingual individuals experience competition between their languages during speech production and their language selection is accounted for by a language control mechanism that aims to reduce the degree of interference. Language switching performance should be influenced by the degree of interference associated with task demands. The degree of interference can be also modulated by several factors, such as individual language proficiency or dominance, that determine or at least approximate baseline language activation during switching (Kroll et al., 2006). The contributing factors also consist of specific task demands, such as preparation time or voluntary switching instruction, in line with the domain-general aspect of language control. To my knowledge, there are very few studies examining the interaction among individual proficiency (otherwise dominance), baseline activation of languages, and degree of interference that may modulate the language control processes in a given switching context. In order to understand the underlying mechanism of language selection and control, it will be also crucial to study how switching performance could be affected by both task-specific and language-specific characteristics associated with control demands.

Moreover, recent findings concerning bilingual language control imply that both language suppression and activation contribute to interference control during switching, leaving other potential control processes largely under-investigated (beyond the notion of inhibitory control). There have been very few studies investigating how interference control processes
during bilingual lexical retrieval may adapt to varying demands of switching contexts that are induced by task factors related to levels of task set (or language set) activation. In particular, the current study aimed to understand how the control mechanism operates in certain switching contexts by manipulating the degree of switch frequency, which stimulates a more or less competitive language switching context, and by contrasting language predominance, which signals a more L1 dominant versus L2 dominant switching context. Thus, the present study aimed to extend the previous language switching studies by considering wide-ranging contexts of switching in conjunction with the contribution of task set and language set activation to the control processes (beyond the trial-by-trial, transient interference control). With respect to the language-specific effect on language control, accompanying question to note was whether or not the factors that modulate activation levels of language sets (to simulate a matrix language in a language switching condition) will interact with individual language proficiency (or dominance) during language switching.

3.1.2. Objective of the study and research design

The aim of this dissertation study was to address these gaps and to gain some clarity on interference control in language selection and switching by questioning whether highly proficient bilingual speakers would be sensitive to varying levels of switching demands associated with either a task- or language-specific manipulation.

One approach for studying whether bilingual switching mechanisms are unique to language or general across domains is to investigate factors that contribute to non-linguistic task switching in the domain of language switching to understand the extent to which the control mechanism is shared between domains. I was particularly interested in whether and how interference control processes could be modulated by two factors of task set activation: one
related to the frequency of switches (i.e., probability of the occurrence of a switch; Mayr, 2006) and, another related to proportional occurrence of each language in different task conditions, which have not been studied in the domain of language switching. Two manipulations - switch frequency and language predominance - were utilized in this study: I first manipulated the switch frequency to differentiate varying degrees of interference in language switching conditions by contrasting the frequency\(^2\) of switch trials (e.g., 75\% versus 25\% of switch trials). Independently, I set the predominance of a specific language based on the differential level of language activation by proportional changes for each language in the switching conditions (e.g., 75\% of English trials with 25\% of Korean trials) for a given lexical selection task.

For the specific effect of switch frequency, performance in Dense-switching and that in Light-switching conditions were compared. My prediction was based on the finding of a task switching study in which Nessler, Friedman, & Johnson (2012) observed reduced local switch costs but increased global switch costs in the high switch-frequency condition (or Dense-switching condition) compared to the low switch-frequency condition (or Light-switching condition). In the similar vein to task switching (Nessler et al., 2012), I would argue that the two languages of bilingual speakers would be highly active and competitive in the Dense-switching condition, relative to the Light-switching condition. Thus, I expected dissociable effects of the switch frequency on different markers of local versus global switch costs during language switching, indicating areas of the shared control processes between task switching and language switching domains. Yet, equivalent versus uneven numbers of switch and stay trials between the two languages in the Dense-switching and the Light-switching conditions could give an

\(^2\)In the task switching literature, the effects of switch probabilities are examined by manipulating the probability of switch trials (e.g., 25\%, 50\% or 75\%; Experiment 4 of Monsell & Mizon, 2006). In the current study, we use the term \textit{switch frequency} to contrast the two conditions with more frequent versus less frequent switch trials.
independent effect of switch frequency (apart from an effect of activation derived from the representation strength) because the number of trials is equivalent between the two languages in both conditions.

For the effect of language predominance on interference control, switching performance in Korean-predominant and in English-predominant conditions were compared. I reasoned that the language predominance in each of mixed-language conditions would stimulate stronger vs. weaker levels of activation between representations of the two languages (while the degree of switch frequency is kept constant). Being prevalent of a specific language may increase the level of baseline activation for the language relative to the other language in a given condition, presumably resulting in varying levels of interference between the languages. The differential effects of language predominance on language selection and control could further interact with individual language dominance whether it facilitates or interferes with individual naming performance.

3.2. Research questions & hypotheses

3.2.1. Research questions

*Research Questions:*

1) Do bilingual speakers demonstrate the differential effects of the switch frequency on different markers of control during language switching that may suggest a domain-general aspect of language control? More specifically, do local switch costs decrease with increasing switch frequency, whereas global switch costs increase when the switch frequency is high?

2) How does language set activation, as assumed to be stimulated by language
predominance, interact with individual language dominance for resisting cross-language interference during bilingual language switching? Specifically, do highly proficient bilingual speakers demonstrate clear evidence for asymmetry in switch costs in a predominant language condition that results from the interaction with individual language dominance (as reflected by baseline naming abilities)?

3.2.2. Hypotheses

**Hypotheses:** The specific hypotheses are the following:

1) Overall, I expected to find a larger switching effect, as reflected by a performance difference between switch trials and stay trials, in the Light-switching condition (low-switch frequency) than in the Dense-switching condition (high-switch frequency) due to increased interference. When both languages are active and competing with a high switch rate, then the control processes should operate in both stay and switch trials in the frequent switching context. Thus, the local switch cost was predicted to be small in the Dense-switching condition; however, the global switch cost was predicted to be large because participants would experience high competition between the languages, which are maintained at a high level of baseline activation even in stay trials of the language-mixed condition.

2) In contrast, the high proportion of stay trials in the Light-switching condition would result in a relatively low level of overall competition between the two task representations due to imbalance of activation levels between trial types. Along with infrequent switches, however, a greater degree of interference should emerge particularly on switch trials than stay trials in the Light-switching condition, producing a
large local switch cost but a small global switch cost. Note that the activation levels of representations would be comparable between the two languages because of the equivalent number of trials for the languages. Thus, the effect of switch frequency would be expected to be independent of (or least affected by) individual language dominance given that high versus low competition is assumed to occur at the task representations, which may modulate the control processes, rather than at the language representations. Taken together, a robust domain-general effect of this experimental manipulation on language control may not interact with a between-subject variable as prior switching studies did so (e.g., Ma et al., 2015).

3) I also expected to find an effect of stimulus language predominance on bilingual lexical retrieval, as measured by different switching patterns between the Korean-predominant switching condition and the English-predominant switching condition. This effect, unlike that of switch frequency, was expected to interact with a between-subjects variable, such as individual language dominance, because both task demand and individual variable can affect the level of baseline language activation. Therefore, an interaction effect on switching performance associated with participants’ individual language dominance (i.e., depending on their baseline performance difference between the two languages: L1 dominant or L2 dominant) was expected. That is, English-dominant bilingual individuals are expected to show an overall performance decrease (i.e., less accurate and/or slower response time) in the Korean-predominant switching condition as compared to the English-predominant condition, whereas Korean-dominant bilingual individuals would show the opposite pattern. As individual dominance was determined by bilinguals’ baseline measures (i.e., single language conditions), they were
expected to perform better in the condition in which their language dominance matches the language predominance condition.

4) In addition to the primary predictions, the switching effect can further interact with languages across conditions. Further hypotheses about asymmetry in switch costs across conditions follow below.

For the switch frequency manipulation, the domain-general task demands by switch frequency may not be necessarily parallel to the level of competition among co-activated language representations, as mentioned above. Furthermore, if the (inhibitory) control would reactively respond to high competition between co-activated language representations (e.g., Bobb & Wodniecka, 2013), the finding of asymmetrical switch costs would be subtle or absent. In contrast, the asymmetry was expected in language-dependent ways for the language predominance manipulation: English-dominant bilingual individuals would produce a clear pattern of asymmetry in the Korean-dominant switching condition relative to the English-dominant switching condition. The expected interaction effects with individual language dominance would arise because English-dominant bilinguals face larger interference between languages in the Korean-dominant switching condition in which they constantly control their own dominant language to activate the target language. In contrast, Korean-dominant bilingual speakers would produce a clear pattern of asymmetry in the English-dominant switching condition relative to the Korean-dominant switching condition because the dominant language, Korean, had not been used and was not affected by interference from the other language.
Chapter 4. Methods

4.1. Participants

Forty-five Korean-English bilinguals participated in this study. All participants were young adults between the ages of 18 and 35 years (mean age = 28.9, SD = 3.9) with no history of any neurological disorders, learning disabilities, speech-language problems, or cognitive deficits. Participants were recruited via advertisements in the greater New York City area. A brief phone screening was administered to ensure that participants met the inclusionary criteria, with the two critical criteria being: (a) both languages were currently and actively used, and (b) the speakers were fluent enough to carry on a conversation with native speakers of either language. During screening, each potential participant answered several questions related to basic demographic information (e.g., age, gender, level of education), medical and educational history (e.g., any learning disorders or visual problems), and language history (e.g., individuals’ dominant language between L1 and L2, language learning environment: home or school). All information has been kept confidential by separating the identifying information from the data set. Informed consent was obtained at the time of testing from each participant and was stored in a locked cabinet in the Cognition and Language Laboratory at the Graduate Center of the City University of New York. Data organization and analysis were done using non-identifying codes for participants by using password-protected files on a computer with restricted access to only key study personnel.

Table 1 illustrates the characteristics of our 44 participants (27 females and 17 males) who completed the experimental testing. All bilinguals were residing in the United States at the time of testing, although the length of residence varied across participants (M = 14.4 years; SD

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3 One participant withdrew from the study voluntarily and did not complete testing. No data from that participant were included in the analyses.
While all participants reported learning to speak Korean at home as their first language, there were 3 early, simultaneous bilinguals who reported learning both languages, Korean and English, from birth at home. Self-reported individual dominance was classified independently of which language was a participant’s first language: 24 participants reported being Korean-dominant and 20 participants reported being English-dominant.

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4 To ensure that these early bilingual data did not impact our results, proficiency, self-rating dominance, and naming baselines of the early bilinguals were compared to the rest of the group at a preliminary stage in the analysis. The data from these 3 participants did not differ from the rest of the group, so their data were included in the analyses.

5 Participants were asked to list their languages in order of “dominance” and the first language listed was considered as their dominant language. Note that the self-reported dominance did not show a clear match with their performance on the proficiency test or their naming baseline measures. It appears, then, that the self-reported dominance as a general question does not fully represent the underlying constructs and/or characteristics of language dominance, and the way dominance is perceived may vary across individuals.
Table 1. Characteristics of bilingual participants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>age (years)</td>
<td>28.9</td>
<td>3.9</td>
<td>23</td>
<td>36</td>
</tr>
<tr>
<td>education (years)</td>
<td>16.5</td>
<td>2.1</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>length of stay in the U.S. (years)</td>
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<td>6.8</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>Age of acquisition of Korean (years)</td>
<td>0.3</td>
<td>0.8</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Age of acquisition of English (years)</td>
<td>8.7</td>
<td>3.7</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>Korean reading ability (^a)</td>
<td>6.3</td>
<td>1.0</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Korean writing ability</td>
<td>6.1</td>
<td>1.2</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Korean speaking ability</td>
<td>6.5</td>
<td>0.9</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Korean listening ability</td>
<td>6.5</td>
<td>0.8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>English reading ability</td>
<td>6.1</td>
<td>0.8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>English writing ability</td>
<td>5.8</td>
<td>1.1</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>English speaking ability</td>
<td>5.9</td>
<td>1.0</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>English listening ability</td>
<td>5.9</td>
<td>1.0</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Percent Korean use currently</td>
<td>48.7</td>
<td>18.6</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>Percent English use currently</td>
<td>51.3</td>
<td>18.6</td>
<td>20</td>
<td>95</td>
</tr>
<tr>
<td>Switching frequency currently at sentence level (^b)</td>
<td>2.5</td>
<td>1.2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Switching frequency currently at word level</td>
<td>2.9</td>
<td>1.3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Synonym naming in Korean (percent correct)</td>
<td>62.7</td>
<td>22.2</td>
<td>6</td>
<td>100</td>
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<tr>
<td>Synonym naming in English (percent correct)</td>
<td>69.2</td>
<td>19.2</td>
<td>22</td>
<td>100</td>
</tr>
<tr>
<td>Synonym naming accuracy difference (^c)</td>
<td>6.5</td>
<td>28.2</td>
<td>-47</td>
<td>81</td>
</tr>
</tbody>
</table>

Note: \(^a\) Self-ratings were on a scale from 1 (little or no knowledge) to 7 (like a native speaker). \(^b\) “When speaking to bilinguals, how often do you switch languages?” ratings were on a scale of 1 (almost never), 2 (occasionally), 3 (2–3x per conversation), 4 (several times per conversation), 5 (a lot, or sometimes even constantly). \(^c\) English percent accuracy – Korean percent accuracy.
4.2. Behavioral Measures:

4.2.1 *Bilingual language use/history questionnaire*

A modified language background questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007; Li, Sepanski, & Zhao, 2006) was administered to obtain information related to individual language history and experience (e.g., age of acquisition, age of arrival, and length of stay in the U.S.). This information is summarized in Table 1.

4.2.2 *Proficiency test*

A modified synonym-naming test based on the subtest of the Bilingual Verbal Ability Test (BVAT; Cummins, Muñoz-Sandoval, Alvarado, & Ruef, 1998) was administered to assess individual levels of proficiency and to provide a more in-depth measure of lexical knowledge and lexical production. Performance on this test was considered to measure lexical proficiency in each language. The synonym naming subtest of BVAT was selected to assess language (oral) proficiency at the lexical level because the types of task (i.e., word naming) and stimulus (nouns, verbs, & adjectives) did not overlap with items on the experimental picture naming task. Bilingual performance on this task has been reported to correlate with self-ratings (e.g., Filippi et al., 2013) although the medium to high correlation that they reported was not found in the current study. Note that the BVAT subtest was modified to replace four lexical items with more culturally appropriate words since they were not commonly used in one of the languages. In addition, two stimulus words that did not have translation equivalents were excluded from the list for both language conditions. Thus, eighteen items were included in the modified version of

---

6 The synonym naming test (rather than a traditional vocabulary test) was used in the study to avoid any overlap between stimuli in our experimental task and a proficiency test because a number of lexical items were shared in both traditional vocabulary tests, such as the Peabody Picture Vocabulary Test (PPVT) or the Boston Naming Test (BNT), and the experimental task.
the synonym naming task for each language condition, and the proficiency test was converted to a computerized version using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA).

In this test, participants were instructed to produce a synonymous word in the same language as the target word, which was presented on the screen for 5000 ms. Two versions of the synonym naming test were given, a Korean and an English version in a counterbalanced order across participants, with 18 words presented in each language. Each language condition began with three practice items to acquaint participants with task demands and to provide feedback on their practice performance. The dependent variables included accuracy (% correct) and response time (ms). Based on the total possible score of the test, which was 18 in each language condition, the accuracy was calculated. Note that participants’ responses on the Korean synonym test were later checked for accuracy by two raters who were identified as native speakers of Korean and fluent English speakers. Participants did not receive any point for items when they responded in the other language. Participants received a half point for items in the following examples: 1) a response with similar meaning but the grammatical class is different from that of stimulus word (e.g., “less” for “reduce”; “collect” or “sum up” for “cumulative”); 2) a response which is considered to be from a superordinate category (e.g., “transportation” for “car”) or a subordinate category (e.g., “BMW” for “car”). The interrater reliability measured using Pearson’s R was high ($r = .97, p < 0.001$).

Synonym naming accuracy (%) served as an indicator of vocabulary size in each language. Assuming that relative difference between the two languages in proficiency can be reflected by different vocabulary sizes between the languages, I correlated the two measures, self-rated proficiency and the synonym naming accuracy, in each language. The correlation
between self-rated proficiency and the objective measure of proficiency (synonym naming accuracy) was moderate ($r = .475$, $p = .001$ for Korean; $r = .412$, $p = .005$ for English). Note that some of the participants demonstrated very low performance on this test although they had reported above average proficiency at the screening (according to the inclusion criterion). The observed discrepancy between self-report and the performance on the test may relate to the particular test in which they were asked to use academic vocabulary knowledge in a complex way.

4.3. Experimental Measures: Language switching experimental task

I developed the experimental naming task following the format of traditional picture naming tasks (e.g., Boston Picture Naming Test, BNT; Kaplan, Goodglass, & Weintraub, 1983). In the current study, the picture naming experiment was computerized using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) in order to present colored picture stimuli in a consistent way and to automatize the collection of data related to naming response accuracy and reaction time via voice-key trigger. Pilot tests were performed at an initial stage of developing the experimental design: I evaluated the feasibility and required time-costs when executing the task with the proposed set of stimuli and manipulations. As a result, the stimulus set and experimental procedures were modified based on the preliminary data.

4.3.1 Stimuli and procedures

The experimental task consisted of two baseline conditions (i.e., English and Korean language baselines), two switch-frequency conditions (a Dense-switching and a Light-switching condition, each containing an equal proportion of words in each language), and two language-predominance conditions (an English-predominant condition containing 75% English words and
25% Korean and a Korean-predominant condition containing 75% Korean words and 25% English words).

The two baseline conditions consisted of 20 stimulus words each with no language switching in either block. The switch-frequency conditions included a balanced number of trials between the two languages (i.e., 21 Korean trials and 19 English trials in the Dense-switching; 19 Korean trials and 21 English trials in the Light-switching condition). The difference between the two switching conditions lay in the number of switch versus stay trials used to vary the frequency of language switching (i.e., 13 stay and 26 switch trials in Dense-switching; 26 stay and 13 switch trials in Light-switching conditions). The language-predominance conditions set the switch frequency evenly between the two conditions (i.e., 21 stay and 18 switch trials), but the proportion of each language was manipulated in each condition in order to vary the level of activation for each language (i.e., 30 Korean and 10 English trials in the Korean-predominant condition; 30 English and 10 Korean trials in the English-predominant condition). The presentation order of the stimuli in each condition was fixed to control the proportion of switch versus stay trials and the proportion of each language. The experimental conditions and trial types are described in Table 2.

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7 The combined number of switch and stay trials (39) is not the same as the total number of trials (40) because the first stimulus word is not classified as a stay nor a switch trial and was thus excluded from the data analysis.
Table 2. Description of trial types and conditions in the experimental task

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Korean condition</th>
<th>English condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td># of stay trials</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td># of switch trials</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Experimental 1</td>
<td>Switch-frequency</td>
<td></td>
</tr>
<tr>
<td># of stay trials</td>
<td>13</td>
<td>26</td>
</tr>
<tr>
<td># of switch trials</td>
<td>26</td>
<td>13</td>
</tr>
<tr>
<td># of Korean trials</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td># of English trials</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Experimental 2</td>
<td>Language-predominance</td>
<td></td>
</tr>
<tr>
<td># of stay trials</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td># of switch trials</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td># of Korean trials</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td># of English trials</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

Stimuli were presented at the center of a 16-inch computer screen set to 1280 X 1024 pixel resolutions, viewed at a distance of approximately 30 inches. In each language baseline condition, 20 picture stimuli were presented after six practice items. Each trial was structured in the following way: (i) a fixation point on a black background was presented for 500 ms; (ii) a picture stimulus appeared on a black background for a maximum of 5000 ms or until the participant responded. In each language-switching experimental condition, 40 picture stimuli were presented after six practice items. Each of the mixed-language conditions was structured the same as the baseline conditions with the exception that a language cue (a Korean flag for Korean; a United States flag for English) was simultaneously presented with each picture stimulus on the
lower right side of the screen indicating which language to use. Thus, in the language-switching conditions, participants were instructed to name the stimulus in the target language indicated by the visual cue (flag). The presentation of the experiment and timeline of trials are described in Figure 1.

A total of 120 picture stimuli were selected from a set of 260 colored line drawings (Rossion & Pourtois, 2004), which was based on the widely used database of black-and-white line drawings (Snodgrass & Vanderwart, 1980). For the current study, the picture stimuli were selected according to the following exclusionary criteria: 1) exclusion of any pictures whose naming accuracy was below 40% in the normed database (Rossion & Pourtois, 2004), 2) exclusion of any compound nouns, Korean-English cognates defined as a lexical borrowing from the other language, culturally inappropriate or unfamiliar words (including extremely low frequency or words that are nonexistent in a frequency database for either language, CELEX, English Syntax, Lemmas dictionary; Yonsei Corpus database, 1998), 3) exclusion of any pictures that can be named by more than one acceptable names in either language (e.g., mittens/gloves; rooster/chicken; 머리카락/머리칼/머리), and 4) exclusion of words with more than three syllables in either language.
Note: The language cue (a Korean flag for Korean; a United States flag for English) was not presented in the Baseline conditions since the target language was given when instruction was provided at the beginning of each baseline condition.

After the words were selected, the stimulus lists were created to match word frequency counts and number of syllables between experimental conditions and between languages. In order to control possible effects of word frequency on naming speed, the average frequency score was calculated with English frequency counts and Korean frequency counts for each stimulus item. Although the selected stimuli varied in terms of frequency counts in each language (CELEX, English Syntax, Lemmas dictionary; Basyen, Piepenbrock, & van Rijn, 1993; Yonsei Corpus database, 1998), the correlations between frequency counts in English and Korean were moderate ($r = .445; p < .001$). Stimulus words were then ranked according to their mean frequency counts and then evenly distributed into three groups of 40 items each (40 items for the baseline conditions; 40 items for the switch frequency conditions; 40 items for the language-predominance condition). Thus, the average frequency was similar across the three types of
conditions (M = 1357, SD = 1806 in the baseline conditions; M = 1416, SD = 1888 in the switch-frequency condition; M = 1442, SD = 1891 in language-predominance condition). The 40 baseline items were composed of 20 words for the Korean baseline condition and 20 words for the English baseline condition. The frequency counts were further matched between switching trials and non-switching trials within each experimental condition, so that differences between switch and non-switch trials would not be confounded by the frequency effects in the language-switching paradigm. The stimuli were also matched in terms of the number of syllables between conditions and between languages.

Note that the description of stimuli based on the exclusionary criteria and stimulus selection procedure was finalized after several pilot tests to check the feasibility of the experimental design. The preliminary data from the first two pilot tests (and a survey of participants taken informally) indicated that when participants did not name an item in a given time they were confused by the particular stimulus. Furthermore, the pilot data also showed that the switch cost patterns did not always reflect only participants’ language switching in the picture naming task, rather that switch cost was confounded by other factors, such as their selection of verbal responses among other plausible responses (e.g., whether they name it as “a bird” versus “a sparrow”). Therefore, a familiarization session\(^8\) was implemented before the main experimental task, in order to familiarize participants with all pictures and their corresponding target names. The issues described above were not observed in the main experimental testing.

Participants were tested individually in a quiet room after completing informed consent procedures. The language for instruction during the testing session was determined based on each

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\(^8\) The familiarization session was provided to help bilingual participants skip the classification process for several objects only (i.e., 4% of the stimulus set), not to teach what each object is called. Note that the participants reported at the beginning of the testing session that all stimulus words were words they knew in the languages.
participant’s preference, which was English for the majority of the group (i.e., 75%, n=33). The familiarization session was administered using PowerPoint before experimental testing. Participants were instructed to review the names of all stimuli together with the pictures, followed by a quick test session in which they were asked to name some of the items as directed by the experimenter. During this familiarization phase, participants were allowed to take time to review the materials in a self-paced session. Feedback was given when participants were unable to name a picture correctly. During the testing session, the experimental tests were counterbalanced across participants. Among the naming tasks, the baseline conditions (i.e., single-language blocks) were administered first with the order of the two language conditions counterbalanced across participants. The experimental conditions (the two switch-frequency conditions and two language-predominance conditions) were also counterbalanced within and between conditions. In other words, the order of manipulation (i.e., switch-frequency and language-predominance) and the order of presentation within each manipulation (i.e., two conditions for each manipulation) were counterbalanced across participants.

The synonym proficiency test and the language background questionnaire were administered after three blocks of the experimental test and the order of the proficiency tests for the two languages were also counterbalanced across participants. Participants completed the testing session in approximately one and a half hours, and breaks were given if needed. The naming experiments were administered using E-Prime software on a computer to which a serial response box was directly connected, which collected response time data based on a voice-key trigger through a headset microphone. A schematic picture of the hardware setup for the experiment is presented in Figure 2.

During testing, the experimenter manually recorded the naming responses of each
participant while the E-Prime program also collected accuracy and response time via voice-key. An auditory recording was set up because the voice-key accuracy was not appropriate, especially when wrong responses or nonresponse related noise (e.g., cough or fillers) were produced by the participants. Thus, the recordings of the responses were checked following testing to verify response accuracy and response time. In addition, a very brief marker tone (15 ms) was inserted at the onset of the presentation of the picture stimuli to serve as an indicator to designate the onset of the presentation because the auditory recording produced no trial by trial latency data (see Figure 3 for the measurement of naming response latency on a recorded sound file). A continuum of the latency data in each naming block needed to be segmented to label each trial according to the marker tone of stimulus onset (Roon, 2013). This tone sounded like a click and it was very transitory, so it was expected to have very little effect on participants’ naming performance. If the tone had any effect, it was equal across participants. All spoken response latencies were checked by visual inspection while the onset of the marker tone (as the stimulus onset) and the onset of a verbal response were marked in a speech-processing program (Praat; Boersma & Weenik, 2007). Then response latencies were automatically calculated by written scripts using the program. The measurement of naming response latency in each trial is described in Figure 3.
Figure 2. Schematic of the hardware setup for the experiment
4.4. Data analysis

Data processing before the analyses was as follows: The dependent variables in each naming condition consisted of performance accuracy (\%; ACC) and response time (ms; RT), and the independent variable was condition (baseline and experimental blocks). Proficiency performance was also analyzed with dependent variables of performance accuracy (\%; ACC) and the independent variable of language (Korean and English).

Mixed-effects regression analysis was used to examine accuracy and response time (RT) data. Two sets of analyses were conducted using mixed-effects models (Baayen, Davidson, &
Bates, 2008). The first analysis aimed to establish the presence of switch-frequency effects in the Light-switching and the Dense-switching task conditions. The factors for this analysis consisted of 1) trial type (switch vs. stay), 2) language (Korean vs. English), 3) switch-frequency condition (Light- vs. Dense-switching), and their interactions. Baseline measures in both languages were centered and entered as covariates into the analyses. The second analysis was performed to investigate the effect of language-predominance on language switching in Korean-predominant and English-predominant task conditions. The factors for this analysis contained 1) trial type (switch vs. stay), 2) language (Korean vs. English), 3) language-predominance condition (Korean- vs. English-predominant), and their interactions. In addition to the variability within subjects, between-subject variability (e.g., proficiency, language dominance, etc.) was taken into account when fitting the models.

For accuracy data, mixed-effects logistic regression models were fit with family binomial and link logit. For RT data, the models were fit based on linear mixed-effects regressions with Maximum Likelihood as the estimation method. Data screening of distribution and outliers preceded analyses. For accuracy, between-subject outliers (based on the group’s data) were identified based on 3 SD above or below the group mean. Following the outlier screening, all data from one participant were excluded from the analyses involving accuracy data due to very low level of accuracy. Only correct responses were selected for RT analyses. Despite the slightly skewed distribution, RT data were kept in their original scales because analyses performed on transformed data produced the same pattern of results. Within- and between-subject RT outliers were trimmed based on a 3-stage procedure: 1) extreme data points were excluded based on an absolute cutoff criterion of $\leq 200$ ms or $\geq 5000$ ms; 2) RT data more than 3 SD below or above the individual mean were excluded (within-subject level); 3) participants whose mean score was
more than 3 SD below or above the group mean were excluded (between-subject outliers from the group). As a result of the third criterion, all data from one participant were excluded from RT analyses. The outlier screening led to the exclusion of less than 3% of the total data.

In mixed-effects modeling, a step-wise approach was performed and the final model was established for every analysis; however, only the final model is reported. Participants and items were treated as random factors. For each final model, both level-1 and level-2 standardized residuals were examined; models were refit without observations with residual values more than 3 SD below or above the mean. The results are reported in the analysis sections 5.2.3. and 5.2.4., including all possible main effects and interactions as fixed effects. Effects reported from these analyses include estimates, standard errors, \( t \) values, and \( p \) values. Data were analyzed with R-studio using the following packages: Lmer for RT data and Glmer for accuracy data. In this study, effects are reported as significant for \( p < .05 \).
Chapter 5. Results

5.1. Language profile

Demographic characteristics of the participants were already described in Table 1. Of particular interest was to determine the group profile of the bilingual speakers based on several pertinent measures of bilingualism: age of acquisition (AOA), language proficiency, and dominance. Overall as a group, mean AOA between Korean and English was significantly different, \( t(43) = -14.92, p < .001 \). All participants learned Korean as their first language; however, the age of acquisition of English varied with a wide range from 0 (birth) to 17 years. Thus, this group of Korean-English bilinguals consisted of both early, simultaneous bilingual speakers and late, sequential bilinguals; the majority of the group was considered late bilingual adults; there were relatively few early bilingual adults (\( n=3 \); mean AOA of English was 8.7 years; mean AOA of Korean was 0.3 years).

Note that both subjective and objective measures of proficiency indicated that the participants as a group exhibited a similar level of proficiency between the two languages: their self-ratings of proficiency and lexical proficiency scores on the synonym naming task did not significantly differ between English and Korean, \( t(43) = 1.88, p = .067 \) for self-ratings; \( t(43) = 1.53, p = .133 \) for synonym naming scores, respectively. Note that the objective measure of proficiency, i.e., synonym naming scores, was utilized in the data analysis because the range of the self-rating was relatively narrow (5-7 on a scale) and the measure was less appropriate than the synonym scores. Individuals’ language dominance was later judged in the analyses based on their relative difference between the two languages, i.e., baseline naming speed (see section 5.2.1).
5.2. Naming performance in baseline and experimental conditions

5.2.1. Descriptive data

Accuracy

Participants performed reliably well, with a mean accuracy of 95%. Accuracy on the two baseline conditions was significantly different: participants performed more accurately in English than in Korean, \( t (1, 42) = 3.305, p < .005 \). An overall performance decrease was observed with experimental manipulations, as evident from the descriptive statistics (Table 3).

Accuracy performance on the baseline and experimental conditions differ statistically, \( t (1, 43) = 29.08, p < .001 \); \( t (1, 43) = 9.03, p < .001 \); \( t (1, 43) = -29.11, p < .001 \); \( t (1, 43) = -9.91, p < .001 \).

Table 3. Descriptive statistics of performance accuracy and RT data

<table>
<thead>
<tr>
<th></th>
<th>Accuracy (%)</th>
<th>RT (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>97 (4)</td>
<td>93 (8)</td>
</tr>
<tr>
<td>English</td>
<td>899.91 (160.32)</td>
<td></td>
</tr>
<tr>
<td>Korean</td>
<td>1052.51 (237.19)</td>
<td></td>
</tr>
<tr>
<td><strong>Experimental</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switch frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>93 (5)</td>
<td>94 (5)</td>
</tr>
<tr>
<td>Dense-sw</td>
<td>1430.19 (185.79)</td>
<td></td>
</tr>
<tr>
<td>Light-sw</td>
<td>1384.48 (186.66)</td>
<td></td>
</tr>
<tr>
<td>Language predominance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>94 (4)</td>
<td>94 (8)</td>
</tr>
<tr>
<td>Korean-prd</td>
<td>1437.82 (185.79)</td>
<td></td>
</tr>
<tr>
<td>English-prd</td>
<td>1291.22 (171.00)</td>
<td></td>
</tr>
</tbody>
</table>

*Note: sw means switching condition; prd means predominance condition; code. *** \( p < .005 \)*

Response time

Overall, participants were faster in the English baseline condition than the Korean baseline condition, \( t (1, 42) = -5.231, p < .001 \). Speed on the two baseline conditions was faster
than that in the experimental conditions, with an average speed difference of 410 ms.

Furthermore, the RT results of experimental conditions revealed that overall naming performance was not different between the Dense-switching and Light-switching conditions, $t(1, 43) = .415, p = .680$. However, overall performance in the language-predominant conditions showed a significant difference: slower performance in Korean-predominant than English-predominant conditions, $t(1, 43) = 5.683, p < .001$. The main effects of experimental manipulations will be fully discussed in the next sections.

5.2.2. Effect of switch frequency

**Accuracy**

A mixed-effects logistic regression analysis was performed on accuracy data to examine whether there was any effect of interference on lexical retrieval performance in relation to the switching demand. Because the baseline data revealed the relationship between levels of lexical proficiency between the two languages and naming accuracy, individual proficiency measures (as measured by synonym naming scores) were entered as a covariate\(^9\) in the models. The independent variables (condition, trial type, and language) were entered when models had been established. The Level 1 model was built by including the English stay trials Dense-switching condition as a reference level along with the proficiency score as a covariate variable. Only the independent variables: condition (i.e., Dense-switching vs. Light-switching), trial type (switch vs. stay), and language (English vs. Korean) improved the model fit, $\chi^2(1) = 3, p = .036$; however, the interaction effects did not yield a better fit to the data in subsequent models, $\chi^2(2) = 2.27, p = .322$. Therefore, the final model excluded any interactions (Table 4). According to the final

---

\(^9\) Baseline scores were first entered as covariates; however, the model fit was not established. Therefore, individual level of lexical proficiency was controlled in the models. No interaction effects with language proficiency or age of acquisition were observed in the models.
model, only a significant effect of language was observed \( (p < .05) \) in the absence of any interactions. This finding showed that individuals performed less accurately in Korean than in English across all conditions.

Table 4. The final model of accuracy data for examining the effect of switch frequency

<table>
<thead>
<tr>
<th>Variables</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>z value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>intercept</td>
<td>2.844</td>
<td>0.180</td>
<td>15.780</td>
<td>0.001 ***</td>
</tr>
<tr>
<td>proficiency</td>
<td>0.001</td>
<td>0.004</td>
<td>0.440</td>
<td>0.650</td>
</tr>
<tr>
<td>condition</td>
<td>0.218</td>
<td>0.144</td>
<td>1.515</td>
<td>0.130</td>
</tr>
<tr>
<td>switch</td>
<td>-0.087</td>
<td>0.143</td>
<td>-0.605</td>
<td>0.545</td>
</tr>
<tr>
<td>language</td>
<td>-0.312</td>
<td>0.138</td>
<td>-2.260</td>
<td>0.024 *</td>
</tr>
</tbody>
</table>

Note: Signif. codes: † p < .10   * p < .05  ** p < .01  *** p < .001

**Response time**

A linear mixed-effects regression analysis was performed on the RT data. Baseline speed measures in the two languages were entered into the models as covariates, along with the independent variables: condition, trial type, and language. Models were first established with within-subject variables and covariates. Then, between-subject variables were entered into the models to examine any effect and interactions of factors at an individual level, such as language proficiency and AOA of English. In the analysis of RT data, variations of subject-level factors did not contribute to the model fit, nor were any effects of proficiency or AOA of English or interactions found, \( \chi^2 (2) = .23, p = .891 \) with proficiency; \( \chi^2 (2) = 2.88, p = .237 \) for AOA of English. Thus, the between-subject factors were excluded from the final model. Note that the final models with and without the random effects were significantly different from each other, \( \chi^2 (10) = 68.64, n = 43, p < .001 \) so random effects were taken into account in the final model.
Nevertheless, the findings were similar in the two models, indicating robust effects of switch frequency, independent of the random effects.

As reflected by the intercept of the final model (see Table 5), the reference measure, which was English stay trials in the Dense-switching condition, was estimated at 1326 ms. Results showed a large main effect of switch-frequency condition with an estimated speed advantage of 141 ms for stay trials in English in the Light-switching condition compared to the Dense-switching condition ($p < .001$). Neither the effects of trial type nor language appeared to be significant, although there was an interaction. The switch-frequency condition X trial type interaction was significant ($p < .001$; estimated difference of switching cost was 210 ms, as measured by the difference between stay and switch trials in English), such that the effect of switching was significantly greater in the Light-switching condition relative to the Dense-switching condition. The switch-frequency condition X language interaction was highly significant ($p < .001$), with an estimated speed advantage of 176 ms for English relative to Korean in the Light-switching condition (see Figure 5). In addition, a significant language X trial type interaction was found ($p < .01$; an estimated switch cost advantage of 120 ms for English in the Dense-switching condition), indicating that speakers demonstrated a larger effect of switching into Korean than into English, in particular in the Dense-switching condition. Furthermore, a highly significant condition X trial type X language three-way interaction ($p < .001$) indicated that the estimated switching effect was smaller for Korean compared to English in the Light-switching condition by 226 ms. As shown by the slope of the lines in Figure 5, a much steeper line for English than for Korean in the Light-switching condition reflects a larger effect of switching into English, whereas a steeper line for Korean than for English in the Dense-switching condition suggests a greater effect of switching into Korean.
Table 5. The final model of RT data for examining the effect of switch frequency

<table>
<thead>
<tr>
<th>Variables</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>df</th>
<th>t value</th>
<th>p value</th>
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<tbody>
<tr>
<td>intercept</td>
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<td>39.11</td>
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<td>43</td>
<td>3.21</td>
<td>0.003 **</td>
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<td>0.41</td>
<td>0.684</td>
</tr>
<tr>
<td>condition</td>
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<td>36.80</td>
<td>244</td>
<td>-3.84</td>
<td>0.001 ***</td>
</tr>
<tr>
<td>switch</td>
<td>31.45</td>
<td>40.09</td>
<td>318</td>
<td>0.78</td>
<td>0.433</td>
</tr>
<tr>
<td>language</td>
<td>25.29</td>
<td>33.30</td>
<td>874</td>
<td>0.76</td>
<td>0.448</td>
</tr>
<tr>
<td>condition X switch</td>
<td>175.91</td>
<td>43.65</td>
<td>3002</td>
<td>4.03</td>
<td>0.001 ***</td>
</tr>
<tr>
<td>condition X language</td>
<td>209.68</td>
<td>45.67</td>
<td>3001</td>
<td>4.59</td>
<td>0.001 ***</td>
</tr>
<tr>
<td>switch X language</td>
<td>120.42</td>
<td>44.14</td>
<td>3002</td>
<td>2.73</td>
<td>0.006 **</td>
</tr>
<tr>
<td>condition X switch X language</td>
<td>-225.47</td>
<td>62.84</td>
<td>3001</td>
<td>-3.59</td>
<td>0.001 ***</td>
</tr>
</tbody>
</table>

Note: † p < .10   * p < .05  ** p < .01  *** p < .001

Figure 4. Switch costs as a function of task condition and language

Note: Switch trials represent the trials in which participants switch into the other language.
5.2.3. Effect of language predominance

**Accuracy**

A mixed-effects logistic regression analysis was conducted to investigate whether language switching could be influenced by language predominance, as defined by the proportional differences in presentation of the two languages. As described above, accuracy baselines did not contribute to the models and so they were excluded. Instead, the proficiency measure was entered to control individual levels of language proficiency when fitting the models. Similar to the effect of switch frequency, the Level 1 model was built upon the English, stay trials of the Korean-predominant condition as a reference level along with the proficiency score as a covariate variable. Only the independent variables: condition (i.e., Korean-predominant vs. English-predominant), trial type (switch vs. stay), and language (English vs. Korean) improved the model fit, $\chi^2 (14) = 20.354, n=43, p < .001$, but inclusion of the interaction effects did not improve the model fit in the following models, $\chi^2 (1) = 1.482, n=43, p = .223$. Therefore, the interactions were excluded in the final model. The final model revealed a highly significant effect of trial type ($p < .001$), indicating that switch trials were consistently less accurate than stay trials, regardless of language and condition. The effect of language was found to approach significance ($p = .071$) in that participants tended to perform more accurately in English than in Korean. The summary of the final model is reported in Table 6.
Table 6. The final model of accuracy data for examining the effect of language predominance

<table>
<thead>
<tr>
<th>variables</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>z value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>intercept</td>
<td>3.415</td>
<td>0.207</td>
<td>16.513</td>
<td>0.001 ***</td>
</tr>
<tr>
<td>proficiency</td>
<td>0.002</td>
<td>0.005</td>
<td>0.422</td>
<td>0.673</td>
</tr>
<tr>
<td>condition</td>
<td>-0.130</td>
<td>0.154</td>
<td>-0.840</td>
<td>0.402</td>
</tr>
<tr>
<td>Trial type</td>
<td>-0.590</td>
<td>0.144</td>
<td>-4.100</td>
<td>0.001 ***</td>
</tr>
<tr>
<td>language</td>
<td>-0.280</td>
<td>0.155</td>
<td>-1.807</td>
<td>0.071 †</td>
</tr>
</tbody>
</table>

Note: † p < .10  *** p < .001

Response time

A linear mixed-effects regression analysis was performed on the RT data. Baseline speed measures in the two languages were entered as covariates in the models. Models were first established and fit with within-subject variables and covariates. Note that the models did not improve their fit when between-subject factors, such as proficiency and AOA of English were entered into the models, nor were any effects of proficiency or AOA of English or interactions found, χ² (1) = .765, n = 43, p = .381 for proficiency; χ² (2) = 2.86, n = 43, p = .24 for AOA of English. Thus, these variables were not kept in the final model. Random effects were taken into account in the final model and the pattern of findings remained consistent in the models, independent of the random effects. Note that the final models with and without the random effects were significantly different from each other, χ² (10) = 52.13, n = 43, p < .001. A summary of the final model is described below and reported in Table 7 and the switching effects as a function of task condition and language are described in Figure 6.
Table 7. The final model of RT data for examining the effect of language predominance

<table>
<thead>
<tr>
<th>variables</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>df</th>
<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1147.60</td>
<td>66.30</td>
<td>1965</td>
<td>17.31</td>
<td>0.001 ***</td>
</tr>
<tr>
<td>baseline_Korean</td>
<td>0.45</td>
<td>0.17</td>
<td>43</td>
<td>2.67</td>
<td>0.011 *</td>
</tr>
<tr>
<td>baseline_English</td>
<td>-0.05</td>
<td>0.12</td>
<td>43</td>
<td>-0.42</td>
<td>0.676</td>
</tr>
<tr>
<td>condition</td>
<td>1.08</td>
<td>64.64</td>
<td>3141</td>
<td>0.02</td>
<td>0.987</td>
</tr>
<tr>
<td>switch</td>
<td>216.19</td>
<td>64.67</td>
<td>3141</td>
<td>3.34</td>
<td>0.001 ***</td>
</tr>
<tr>
<td>language</td>
<td>275.87</td>
<td>66.70</td>
<td>3141</td>
<td>4.14</td>
<td>0.001 ***</td>
</tr>
<tr>
<td>condition X switch</td>
<td>-44.59</td>
<td>91.99</td>
<td>3141</td>
<td>-0.49</td>
<td>0.628</td>
</tr>
<tr>
<td>condition X language</td>
<td>-79.00</td>
<td>71.38</td>
<td>3141</td>
<td>-1.11</td>
<td>0.268</td>
</tr>
<tr>
<td>switch X language</td>
<td>-127.49</td>
<td>71.50</td>
<td>3141</td>
<td>-1.78</td>
<td>0.075 †</td>
</tr>
<tr>
<td>condition X switch X</td>
<td>105.41</td>
<td>101.62</td>
<td>3141</td>
<td>1.04</td>
<td>0.300</td>
</tr>
<tr>
<td>language</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: † p < .10  * p < .05  *** p < .001

As reflected by the intercept of the final model (Table 7), the reference measure, based on English stay trials in the Korean-predominant condition, was estimated at 1148 ms (m4). An effect of trial type was statistically significant (p < .001), and the estimate of the switch cost into English in the Korean-predominant condition was 216 ms. This strong effect indicates that participants took longer to respond on switch trials than on stay trials regardless of the language or condition. There was a highly significant effect of language (p < .001) when staying in each of the languages, but no effect of language-predominance condition (p = .987). The estimated difference between languages on stay trials in the Korean-predominant condition was 276 ms. The effect of language reflects that Korean trials were significantly slower than English trials in both language-predominance conditions. The interactions of condition X language and condition X trial type were not statistically significant (p = .628; p = .268, respectively), and the size of the
interaction effects was negligible. However, the language X trial type interaction approached significance ($p = .074$), with the estimated difference of the switch effect by 128 ms in the Korean-predominant condition. That is, the effect of switching into English was slightly larger than that into Korean in the Korean-predominant condition, indicating a hint of a switch cost asymmetry.

Figure 5. Switch costs as a function of task condition and language

![Graph showing switch costs](image)

*Note: Switch trials* represent the trials in which participants *switch into* the other language.
Chapter 6. Discussion

6.1. Introduction

This study undertook to determine the nature of the language control mechanism, in particular the effects of switch frequency and language predominance on interference control during language switching. Based on prior research, two points of discrepancy in the literature were addressed: how the effects of interference are manifested differently across language switching contexts, and how language control can be modulated by domain-general versus language-specific variables of switching (e.g., preparation time on an experimental task condition, Ma et al., 2015). Furthermore, the mixed findings of asymmetry in switch costs suggest that varying levels of task activation could also contribute to language control beyond the trial-by-trial, transient inhibition. Thus, the current study investigated specific effects of task set activation that have been reported to affect interference control mechanisms during task switching, in the domain of language switching.

The current study aimed to determine whether language control, as reflected by switch costs, can be modulated by 1) switch frequency (between the Dense-switching and the Light-switching conditions), and 2) the predominance of one language in the task condition (between the Korean-predominant and the English-predominant conditions). The following synopsis consists of the main findings of the experiment, presented with respect to the hypotheses and corresponding research questions. I start by reviewing the overall finding across conditions and then discuss specific effects of the task manipulations utilized in the experiments. Finally, the implications of the present study will be discussed in light of language control to consider their theoretical relevance.
6.2. The main findings of the study

6.2.1. Overall L1 disadvantage in naming latency

First, it is worth discussing a remarkable pattern of lexical retrieval performance noted among the bilingual participants. That is, the magnitude of the retrieval latencies was significantly larger for Korean than for English across conditions, indicating an overall naming advantage for English in both baseline and experimental conditions. Surprisingly, this overall naming performance was observed to be independent of individual language proficiency as measured by self-reports and synonym naming performance. The discrepancy between dominance and proficiency relating to participants’ linguistic profile will be discussed in more detail below. Yet, I can argue that our bilingual participants are English dominant speakers based on the consistent naming performance across conditions, denoting a homogenous group.

The overall L1 disadvantage is pertinent to some aspects of the language control mechanisms for bilingual language selection. The slow naming in L1 may result from its suppression in the presence of L2. The suppression of L1 occurs when L2 needs to be highly activated for selection given that its baseline activation should be lower than that of L1. Language dominance can be temporarily reversed based on the current activation levels. Previous studies have reported the reversed effect of language dominance on naming performance (e.g., Kroll et al., 2006): the more dominant language was mostly (and negatively) affected by co-activation and competition between two languages, indicating a greater need for a control mechanism with the dominant language than the less dominant one. Indeed, naming latencies in L1 decrease with language mixing (i.e., in a mixed language condition only), whereas the latencies in L2 remain more or less the same across conditions (i.e., in pure language block conditions and mixed language conditions). One plausible explanation for the slower L1
latencies in the mixed condition is that L2 production was facilitated by global inhibition of the higher level of L1 activation (e.g., Christoffels et al., 2007). In a similar vein, it may not be surprising to find the L1 disadvantage in a mixed condition where the two languages are concurrently activated for selection.

Note, however, that the L2 advantage in naming latency was not limited to the mixed conditions in the present study. It is somewhat surprising to observe the prolonged L1 naming time in single-language blocks because the pattern has been exclusively reported with the presence of L2 in a mixed-language block only (Kroll et al., 2006). The results in baseline naming performance in both the single-language and mixed-language blocks are consistent: slower and less accurate responses in Korean than in English. This finding is unexpected because other studies have not reported any similar patterns. The interpretation, which argues the mixed-language conditions could impose L1 suppression (Kroll et al., 2008), may not be directly applicable to our findings. The need for the (inhibitory) language control should be minimal in the single language blocks due to lack of between-language interference. Rather, the current evidence could be accounted for by a broader scope of the control processes.

It seems pertinent to consider the level of language control based on a complementary assumption of the differential effects of interference relating to the order effect of languages tested in the baseline naming performance. A global inhibitory process may also be required to attenuate a bilingual participant’s activation of the non-target language even in the single-language block condition, where only one of the languages is used (Guo et al., 2011; Misra et al., 2012). The interesting findings from the ERP study by Misra et al. (2012) include a (repetition) priming effect found when the L1 block was presented before the L2 block. In contrast, no such effect emerged when the L2 block was presented before the L1 block, suggesting an effect of
long-lasting global inhibition of L1 from the previous L2 block. The reported results confirm the notion of global language control that seems to complement the trial-to-trial level of local language control.

In an a posteriori analysis, I divided the participants into two subgroups based on the order of baseline conditions: one started L1 baseline naming first (i.e., L1 -> L2 baselines) while the other group began with L2 baseline naming first (i.e., L2 -> L1 baselines). If the control process were modulated by activation levels determined by interaction between naming order and individual language dominance, it would function across single language block conditions. Thus, the slower L1 naming relative to L2 should be observed when the L1 is inhibited during L2 naming (i.e., L2 -> L1 baselines), whereas the effect should be minimal or absent when the L1 baseline was first given before the L2 baseline (i.e., L1 -> L2 baselines). Contrary to my expectation, the further analysis performed did not show the pattern that was expected, that is, both groups showed a L2 advantage in naming speed regardless of which language was performed first during the baseline session. Therefore, L2-first introduced interference could not explain our finding of the overall naming pattern in L1.

As mentioned above, the baseline naming performance in each language was initially expected to correspond with the level of lexical proficiency. However, our bilingual participants exhibited overall L1 slowness in all conditions, independent of individual proficiency level. That is, the baseline results do not align with individuals’ relative proficiency based on similar vocabulary size in L1 and L2 (i.e., on synonym naming tests). The baseline naming performance is often assumed to reflect language proficiency as the language demand in the baselines requires a single task to retrieve lexical items in the absence of language competition (e.g., Bialystok, Craik, & Luk, 2008). It seems the current evidence demonstrates the discrepancy between
baseline naming performance and individual lexical proficiency in each language. On the other hand, individual language dominance was determined based on self-rated language dominance (see the footnote on page 38). As mentioned above, the relative difference between the baseline conditions was not aligned with the self-report measure either. All participants were faster for naming in English than in Korean regardless of their self-reported dominance or proficiency based on the synonym-naming measure. What could be the reason for the discrepancy?

Both theoretical and methodological concerns should be considered in addressing this question. First, the theoretical construct of language dominance is complex. For example, whether the self-report and naming speed difference appear to be measuring the same construct of dominance for bilingual speakers although the current data did not answer the question. Furthermore, whether language dominance can be clearly differentiated from other constructs, such as proficiency, is not as straightforward as it seems. Note also that another aspect of language dominance is often conceptualized as relative performance, such that dominance may characterize the relative proficiency, as measured by performance differences between the languages in certain areas, such as vocabulary size or grammatical skills (Gathercole & Thomas, 2009). Alternately, it may simply illustrate the language which the bilingual individual has most exposure to or uses more (Grosjean, 2010). The key dimensions involved in the degree of language dominance, performance and usage (e.g., Grosjean, 2010; Luk & Bialystok, 2013) are likely to contribute to each measure to a different degree.

The theoretical discussion should be also related to the second point regarding the discrepancy in language dominance due to any methodological variation. I cannot determine whether bilingual speakers reported their dominance based on processing or production skills or on patterns of use. Self-report based on one question about the language to which a bilingual
individual has had the most exposure or frequency of use seems to provide a global measure of dominance. On the other hand, the baseline difference in naming speed provides an objective measure of relative performance in the particular domain of lexical access and retrieval.

Similarly, one may postulate that the methodological factors in task characteristics as well as group characteristics led to this discrepancy regarding the proficiency measures. Based on lack of correlation between individuals’ proficiency (on synonym naming) and lexical retrieval performance (on baselines), it appears these measures of proficiency\(^{10}\) (and the baseline) require different levels of lexical processing demands or focus on different constructs of what we have tried to measure for linguistic profiles at the lexical level. I suspect that the synonym naming test, relative to the picture naming baselines, requires more processing demands and taps a deeper understanding of lexical items in the absence of pictorial cues, as participants first needed to comprehend the semantic meaning from strings of letters in order to generate the synonym word. The types of stimulus words (or grammatical classes) also differed between the experimental baseline task and the synonym test: the picture naming task consisted of colored pictures of concrete, imageable nouns, whereas the synonym naming test included adjective words and verbs as well. The performance measures also differed in that accuracy of the synonym naming\(^{11}\) and performance speed on the naming baselines might tap different constructs of proficiency. The methodological variation in the measures of proficiency may contribute to the results, so future studies should consider the reliability and validity of their

\(^{10}\) Self-rated proficiency was correlated to the synonym naming performance, but not with the baseline naming performance. Note that the range of self-rated proficiency was limited from 5 to 7 on a scale of 0 to 7 since our bilinguals had above medium to high proficiency in both languages. In part, the baseline naming performance may not capture the same construct(s) of proficiency of the other two measures do.

\(^{11}\) Due to the task difficulty, prolonged response times were produced for some of items on the synonym naming test. Therefore, the accuracy measure on the synonym naming test has been selected to reflect the level of lexical proficiency. In contrast, the response time measure on the experimental task has been utilized because accuracy levels were close to ceiling among our participants.
selected measures of proficiency to understand the underlying constructs of language proficiency across multiple measures.

Recall that the inclusionary criteria for participation included identification as a bilingual speaker who demonstrated the ability to fluently speak both English and Korean and currently used both languages in everyday life. The bilingual speakers in this study have acquired high-intermediate or native-like, advanced levels of proficiency at least in one of the two languages. In other words, proficiency in either language cannot be lower than the high-intermediate level. Although the bilingual speakers are proficient and fluent in the two languages, naming speed indicates that they are dominant in English. Thus, the proficiency level, based on vocabulary size, did not reflect their actual lexical processing speed in the baselines. Moreover, one could argue whether lexical access might be less well maintained for L1 relative to L2 to a certain extent. As an extension of the weaker links hypothesis, bilingual speakers could demonstrate a L1 disadvantage in lexical access as a result of reduced frequency of L1 use when L2 becomes more dominant (e.g., Gollan, Montoya, Cera, & Sandoval, 2008). To test the possibility of the reduced frequency of L1 use, possible correlations between participants’ AOA of English and baseline speed were computed. Our data, however, revealed no correlations between AOA of English and English naming response times ($r = .120, p = .438$) or AOA of English and Korean naming response times ($r = -.091, p = .557$), indicating that the overall baseline patterns cannot be explained by the frequency-based weaker links hypothesis. In sum, the overall naming pattern may be attributed to language dominance and/or frequency of the use related to AOA; however, based on the current set of evidence it is not clear the extent to which each variable of the linguistic profile could explain the difference in overall naming speed among our participants.
Note that Costa and Sabastian (2004) also found the L2 disadvantage over L1 in stay trials (in the mixed condition in Exp. 5). According to the authors, the language bias toward L2 may result in (a) the head start in the lexicalization process of L2, and (b) the “hidden language-switch” involved when naming has to be performed in L1. Independent of the language cue of the experiment, participants may begin the lexicalization process, i.e., lexical access, based on their bias toward their weak language, L2. This account would explain our findings to some degree; yet, the bias in language selection and control may not derive necessarily from difference between stronger and weaker language given lack of the clear distinction in our participants.

Alternatively and in a broader perspective, a probable explanation for the naming latency could be the language context in which participants have lived (e.g., the English speaking environment) that might influence efficiency of lexical processing and/or how much the lexical access is less effectively preserved for L1 versus L2. Given that all the bilingual participants have been immersed in an English-dominant language context, the immersion context (living in an English-speaking environment) may give a further boost to improve the naming processes for the group of bilingual participants. Thus, lexical accessibility, in particular baseline naming performance, could presumably be overridden by current language usage or dominance in a certain context.

A comparable yet slightly different effect of immersion context was reported in a previous study (Linck, Kroll, & Sunderman, 2009); L2 learners who have been immersed in an L2 language environment demonstrated reduced L1 access in both comprehension and production, respectively measured by a translation-recognition task and verbal fluency test. In that study, L2 learners in an immersion context produced significantly fewer exemplars for L1 than L2 in the fluency task relative to those in a foreign language learning context, indicating a
stronger effect of language environment than that of proficiency on lexical retrieval. At present, we can only speculate that our proficient bilingual participants in the current study might have developed a context-induced expectation toward the dominant language of their speaking context (i.e., English), resulting in L2 advantage in naming latency. This may further connote an attrition-like L1 decrease in their L2 speaking context due to a global effect of the immersion context on the manner of language control, as claimed by Linck et al. (2009).

In addition to the global effect of environment, the interaction between the languages seems likely to affect the language profile; For example, vocabulary versus grammar is differently affected by both quantity and quality of language input and exposure (e.g., Perez-Tattam et al., 2013). Certain distinctive components of language could be more commonly utilized during daily language mixing or code switching contexts. Accordingly, the particular language interaction may also influence the current finding of an English lexical naming advantage. For example, I speculate that the bilingual participants are more likely to utilize lexical knowledge of L2 while L1 serves as a matrix language for the syntactic structure. Future studies will be important to further determine what contributes to determining language proficiency and dominance. Of course these must employ the best possible questions to determine participants’ language-use profile. One may argue that the manner of language control processes in the immersion context should not necessarily differ from that of the control processes that have been reported in non-immersion contexts. Nevertheless, I speculate that the degree of the control processes can be differentially applied to language selection by the context-induced expectation. In other words, our participants might internally develop a stronger expectation to register English as the primary language for the experimental setting given that they were tested in the immersion context. The stronger context-induced expectation affects the
degree of the control processes, but also alters their form. For example, the control processes
may function proactively rather than reactively from the beginning of the language selection
process even before activation of the other language in the context. This speculation should be
further tested in terms of different types of bilingual language control.

In any case, additional information of bilingual language profile, such as the spoken
language pair and how distinctive linguistic features of the two languages are across several
levels of lexical retrieval processes, may also contribute to the degree and type of control
processes. A recent study by Van Assche et al. (2013) has reported that evidence for global
inhibitory control processes was clearly observed among Chinese-English bilingual adults, but
not among Dutch-English bilingual adults. Based on the finding, the authors argued that non-
shared (or distinctive) linguistic features at the morphologic, orthographic, and syntactic levels
could encourage the Chinese-English bilingual group to employ more globally controlled
processes when compared to the Dutch-English bilingual group. However, the speculation
regarding the immersion context (and together with distinctive linguistic features of the language
pair of Korean and English, similarly to Chinese and English) cannot satisfactorily explain our
findings because the participants in the current study were not compared to a non-immersion
group or other bilingual group with a different language pair. Further work is clearly needed to
advance our understanding of the role of the language environment in bilingual language
processing.

6.2.2. Effect of switch frequency on language switching performance

In addition to the overall naming performance, it is important to discuss language
switching performance in the experimental conditions. First, switch costs were observed across
all mixed language conditions, revealing a robust effect of between-language interference on the
naming performance. A novel finding in the current study was a clear difference between the highly competitive situation (i.e., Dense-switching condition) and the less competitive situation (i.e., Light-switching condition). That is, a larger switching effect (i.e., a greater local switch cost) was obtained in the Light-switching condition (low switch frequency) compared to the Dense-switching condition (high switch frequency). As predicted in Hypothesis 1, our participants produced different patterns in both local and global switch costs between conditions, but in an opposite direction: decreased local switch costs and increased global switch costs are associated with high frequency switching, whereas increased local switch costs and decreased global switch costs are aligned with low frequency switching. Different magnitudes of switching costs between conditions in this study (based on a significant condition X trial type interaction effect) suggests that the switch frequency modulates observed switching performance by varying degree of task competition.

Such a dissociation in the magnitude of local versus global switch costs between the two switch frequency conditions is of particular relevance to discussion regarding the nature of language control. The opposing patterns between stay and switch trials of the Light-switching versus Dense-switching conditions suggest two distinctive characteristics of the language control processes underlying language switching in bilingual speakers. First, the effect of switch frequency being comparable to that in task switching suggests that the domain-general control processes are shared between language switching and task switching. Second, different types of language control are induced during bilingual language switching. I will discuss the findings relating first to the domain-general effect of switch frequency and then return to the second point in more detail.
In the current study, language switching performance varied as a function of switch frequency, which was assumed to modulate the baseline activation level of languages and the degree and/or manner of language control. The parallel pattern of switching performance in the current study to task switching findings was such that the naming speed in stay trials of the Dense-switching context was deliberate, resulting in an increased global switch cost but a relatively small increase in local switch cost along with the high switch rate. In contrast, the naming speed in stay trials of the Light-switching context was little affected based on the low switch rate, resulting in a reduced global switch costs; however, a relatively large local switch cost was seen. This domain-general aspect of language control overlaps with that of task control (Monsell & Mizon, 2006; Nessler et al., 2012). Furthermore, the overall effect of interference associated with switch frequency was independent of individual language dominance, as initially expected. The manipulation of switch frequency in the current study appears to create a domain-general switching context in which language switching performance shares relevant features with task control.

Note the interpretation from the task literature that the varying levels of activation associated with switch frequency also determines the control processes. For example, Nessler and colleagues (2012) argue that frequent switching (i.e., “higher baseline activation” in the frequent switching context) provides a unique context in which both task sets are highly activated and compete for selection, such that the highly competitive switching condition not only increases the demand for task updating or monitoring on stay trials, but also decreases the demand for task reconfiguration on switch trials (Nessler et al., 2012). Accordingly, a (top-down) control mechanism seems to be required for language-set update not only on switch trials, but also on stay trials in the Dense-switching context. The different magnitude between local and
global switch costs within the same experimental condition could reflect potential differences in the control processes responsible for the degree of interference, which relates to language activation even at an earlier stage of lexical selection.

In contrast, the representations of the target language might be strengthened with repetition of the language set, so the naming latency was reduced on stay trials when the switch rate is relatively low for the task. Thus, the repetition of the particular language facilitated the speed in stay trials, resulting in a reduced global switch cost in the Light-switching condition. According to Nessler and the colleagues (2012), decreased global switch cost could have resulted from the relatively lower demand for task updating or monitoring in stay trials of the less competitive switching condition. Along with repetition of a particular task or language set, baseline activation should be reduced for another task or language set in the Light-switching condition. A large degree of interference could have emerged on switch trials due to the imbalanced activation levels (e.g., a higher activation level for the repeated language set relative to the other language set). The less competitive switching condition may increase the demand for the control processes, such as task-set updating, particularly when they are required to activate the relevant task set and/or to inhibit the alternative task-set on switch trials (Nessler et al., 2012).

With respect to the second point about language control, the current study was able to capture the possibility of more than one process of language control based on the relative changes in global versus local switch costs. It should be noted that, to date, most language switching studies have focused on the local switch costs, and that the existing data seem to favor the reactive nature of inhibitory control, as an explanation for the asymmetrical switch costs in bilingual individuals. Yet, some researchers have recently begun asking whether there are several
processes of language control that may not necessarily be mutually exclusive during bilingual language production (e.g., Philipp et al., 2007; Ma et al., 2015). For example, Philipp et al. (2007) have argued that more than one process, in particular persistence of both activation and inhibition, could explain the asymmetry in switch costs. According to the authors, this idea is in line with most language control models (e.g., Declerck et al., 2015; Green, 1998; Schwieter & Sunderman, 2008).

Our bilingual adults revealed somewhat mixed patterns of the asymmetry between conditions as they demonstrated an asymmetry (i.e., a larger switch cost in L2 than L1) in the Light-switching condition, but a reversed asymmetry (i.e., a larger switch cost in L1 than L2) in the Dense-switching condition. Given that both asymmetry (both reversed and typical patterns of asymmetry) and symmetry were observed across conditions in the same bilingual participants, the degree of interference at response selection must have been affected by the switch frequency-associated task demands. In other words, switch frequency in the task conditions seems to provide domain-general switching contexts in which switching performance was least affected by individual language dominance among our bilingual speakers. Therefore, both asymmetrical and symmetrical patterns of switching can be accounted for by the (experimental) language context rather than individual language dominance.

Moreover, our somewhat complex results could support the idea of multiple loci of language control which may occur at not one, but several loci (Bobb & Wodniecka, 2013; Gollan, Schotter, et al., 2014; Kroll et al., 2006). Indeed, varying degrees of interference in the experimental conditions (as a narrow definition of language context) seem to induce language control throughout different stages of lexical processing and language selection, resulting in different magnitudes of local versus global switch costs. Of relevance to our finding, Ma and her
Colleagues (2015) argued that the nature of language control could be proactive based on the finding of a reduction in the global switch costs with preparation time for language selection (at the CSIs of 500ms and longer in exp. 1), indicating proactive control in the stage of language selection before the stimulus is given. The current set of data provides evidence for more than one process of language control that would vary depending on the degree of interference induced in the switching conditions.

It should be mentioned that the large switching effect (i.e., large switch cost) in the Light-switching condition was driven by English. Indeed, the effect of switch frequency was not salient for Korean, the L1, in the bilingual participants of this study, as Korean responses were significantly less affected by the degree of interference associated with switch frequency. In other words, the size of both local and global switch costs for Korean did not differ between the Dense-switching and Light-switching conditions. It is unclear why Korean, relative to English, was least affected by the degree of interference associated with switch frequency. One speculation relates to the ease of lexical access, such that the bilingual individuals in the study might encounter a fundamental difficulty accessing their L1 relative to their L2. In part, the smaller magnitude of switch costs in Korean than in English might be due to the slowed retrieval speed (even in stay trials) in Korean. Thus, it seems that the reduced lexical access in L1 might conceal any effect of switch frequency on L1 performance; however, future investigation of language control will need to address the relationship among relative language dominance, overall retrieval speed, and language switch costs.

In sum, the effect of switch frequency on language switching suggests that the language or general control processes are shared between task switching and language switching to a certain extent, as is widely assumed in the language switching literature. One prominent
viewpoint of the mechanism of bilingual lexical selection relates to the contribution of individual language dominance, as it could account for the relative strength of language representations as a source for asymmetry in local switch costs. The present study further suggests that task demands may also influence the degree of interference and, thus, would modulate the language control mechanism. Although inhibition control has been proposed to cope with between-language interference (based on the asymmetrical switch costs), our findings exhibit both asymmetry and symmetry in switch costs depending on the switching conditions, partially supporting the reactive aspect of language control. The present finding on switch frequency indicated that bilingual speakers, independent of individual dominance, experienced greater interference in the Light-switching condition than in the Dense-switching condition. Considering the global and local switch costs as behavioral indices of different processes of language control and task control, the varying degree of interference across switching contexts seems to be crucial to determine the implementation of different control processes of language control. The current set of results can be taken into account for the supplementary view of multiple loci or more than one processes of language control (e.g., a hint for the role of proactive interference control) in addition to the reactive, persistent inhibition.

6.2.3. Effect of language predominance on language switching performance

Another set of findings emerged from the analysis of the effect of language predominance on the switch costs. The differently weighed activation levels of the language sets were simulated in the language predominant conditions. The predominance of a particular language was hypothesized to increase the activation level and to provide a linguistically dominant context via repetition of the target language set. Korean was highly activated in the Korean-predominant condition, whereas English was highly activated in the English-
predominant condition. One can also assume that the manipulation of language predominance at the task-condition level affects language switching by modulating the levels of control in the switching contexts as well as by interacting with language dominance at an individual level. In the experimental task, the language proportion differed between the two conditions, while the switch frequency was kept constant in order to observe the independent relationship between individual dominance and language predominance in the task conditions (i.e., dominance-dependent effect of language predominance).

The participants of this study showed no overall difference in the effect of language predominance; similar switching patterns were observed for both Korean- and English-predominant conditions. Based on the finding, there was a lack of evidence supporting the effect of language predominance (in the task condition) and/or predominance-related asymmetry in switch costs. Furthermore, no interaction effect was found with language dominance at an individual level although this effect of language predominance, unlike switch frequency, was initially expected to interact with individuals’ language dominance.

The finding from this manipulation suggests that activation levels are more global than the trial-by-trial conditions. With respect to language activation at a global level, it is possible that some factors were confounded to influence the language activation that would also determine control demands associated with the degree of interference between languages. For example, if our English dominant bilingual speakers were able to establish a somewhat solid, stabilized language control mechanism for the immersion context, their language selection processes (based on the representation strength at an individual level) would be less affected by the temporary manipulation that is specific to language activation at the task level. The lack of overall difference between the two language-predominant conditions may be due to combination
of our bilinguals’ language profile (e.g., relatively high proficiency in both languages) and the context-based language activation in conjunction with a small task effect. Akin to the overall naming latency finding, language activation could relate to the dynamics of language selection and control across language contexts. The relationship among variables pertinent to language control needs to be examined further in detail.

Despite the lack of distinctive switching performance patterns between conditions, the switching performance between conditions marginally differs for English based on the trend toward the language X switch interaction effect. That is, participants exhibited slower naming in switch trials from Korean to English in the Korean-predominant condition than in the English-predominant condition due to a larger effect of interference on English in the Korean-predominant condition. It is interesting to note that English seems to function as a more dominant language than Korean in our bilingual participants (in agreement with the L2 advantage in baseline naming latency) since the English stay trials were significantly faster than other trials in both Korean- and English-predominant conditions. It seems that the English stay trials were minimally affected by the varying degree of interference associated with language activation in the language-predominant conditions. The larger switch cost into English in the Korean-predominant condition is consistent with the standard asymmetry reported in the literature. It also subtly reflects the effect of language predominance in the Korean-predominant condition. The evidence based on the current set of data was neither clear nor sufficient to draw the conclusion that language-specific predominance during a task condition contributes to interference resolution at response selection during language switching. Thus, further investigation is necessary to understand language-specific aspects of language control and its interaction with various language contexts.
Taken together, the findings of the current study argue that several factors contribute to the control mechanism for bilingual language switching. Task demands seem to modulate levels of interference, resulting in different degrees of switch costs during language switching. In particular, I examined switch frequency and language predominance in the task conditions. A clear effect of switch frequency was seen while there was no effect of language predominance. The novel finding is that the task demands of switch frequency and language environment-related context both affect the degree of interference and language set activation in the experimental condition. Such effects relating to language activation and interference appeared to affect bilingual language switching and the language control mechanism.

The current finding of both asymmetry and symmetry in switch costs among the same participants contrasts with the previous studies in which either asymmetrical or symmetrical switch costs were mainly related to the role of individual language dominance. Individual language dominance and baseline language activation may not exclusively determine the asymmetry versus symmetry in switch costs. The bilingual speakers in the current study showed varying levels of activation, which contributed to switch costs across task conditions; nevertheless, they exhibited the typical asymmetrical switch costs in the Light-switching and Korean-predominant conditions in which larger interference was created by the particular task complexity. The current evidence did not support my hypothesis on a possible interaction between language predominance in the task conditions and individual language dominance.

Our data indicated a strong, independent effect of the English immersion context on switching performance that appears to offset the role of individual language dominance. By and large, the data support the traditional view of the language control mechanism, suggesting that both language inhibition and activation play a significant role in bilingual language control.
Furthermore, the findings indicate different levels of interference control processes that are influenced by other factors, task demands or language environment, given that the literature seemed to overlook important variables in determination of asymmetry and symmetry switch costs. Of note, in the following section, theoretical implications about language control mechanisms will be discussed based on the assumption that English is the more active language in our participants due to their being tested in the English immersion context in which they live.

6.3. Language control

The current findings have several theoretical implications for the language control mechanism for bilingual language selection. One major question in the bilingual literature has been whether there is a shared control mechanism across linguistic and non-linguistic cognitive domains. Previous evidence for the shared control mechanism was derived by correlating performance between language switching and task switching (e.g., Calabria et al., 2011; Prior & Gollan, 2011; 2013). Although there are mixed findings from previous research investigating a possible link between language switching and task switching (e.g., Calabria et al., 2011; 2015; Gollan, Kleinman et al., 2014; Prior & Gollan, 2011; 2013; Weissberger et al., 2012), our finding regarding the effect of switch frequency (i.e., the similar pattern of switching performance between task switching and language switching) was consistent with the idea that certain control processes can be shared across domains.

Consistent with the task switching result (e.g., Monsell & Mizon, 2006), the effect of switch frequency indicates that a task set activation process may play a substantial role in language control. The similarity between language switching and task switching relates to the differential effects of task demands in particular varying levels of language activation as a function of varying degree of interference by switch frequency. Based on the finding, a shared
control process seems responsible for language activation and selection. Nevertheless, the present finding on both asymmetry and symmetry in switch costs in the same population of bilinguals may indicate a weak association between asymmetrical switch costs and inhibitory language control although the asymmetrical switch costs have been considered evidence in favor of a domain-general (inhibitory) language control among dominant bilingual speakers in the literature. As claimed by some researchers (e.g., Philipp et al., 2007), inhibition may not necessarily be a prevailing mechanism for language selection and control processes among bilingual individuals. Thus, it is important to consider additional complementary aspects of switching and/or naming performance attributed to the language control mechanism beyond the asymmetry in (local) switch costs.

In a recent review, Declerck and Philipp (2015) argue against a single process of inhibition during language selection, suggesting that there may be more than one process, which may (co-)occur. Note that the current set of findings about task set activation still implies that (reactive) inhibition is crucial. Inhibition and activation are not mutually exclusive processes, and both may contribute to bilingual language selection and control mechanisms (Declerck & Phillipp, 2015). In general, inhibition-related processes, such as inhibiting the previous task set and overcoming the inhibition of the now relevant task set (Mayr & Keele, 2000) could be subsumed under constant task-set updating and monitoring (e.g., Monsell, 2003 for task-set reconfiguration) that have also been found to affect switching abilities. The absence of studies on task-set updating and monitoring during language switching makes it difficult to understand the scope of the language control processes; empirical evidence for a bilingual advantage in both performance monitoring and task switching may pinpoint the control processes overlapping between language control and cognitive control (e.g., Marton et al., 2016). Further studies are
needed to investigate the task-set updating and monitoring aspects of the control mechanisms during language switching.

The current study has fairly examined the language control processes across various language switching contexts in which activation of language sets was varied to modulate the other aspects of control processes such as the proactive aspect of language control. For example, the opposite pattern of local versus global switch costs between high competition and low competition seems to derive from different processes underlying the language control mechanism. Some have argued that trial-to-trial, reactive inhibitory processes may not fully explain the mixed findings in terms of asymmetry and symmetry in local switch costs (e.g., Christoffels et al., 2007; Green & Abutalebi, 2013); not only local switch costs but also global switch costs have to be taken into account to learn about the control processes of bilingual language production (Ma et al., 2015). Thus, I speculate that the extent of inhibition of the non-target language depends not only on the relative proficiency of the bilinguals’ two languages, but also on the relative activation levels of particular language sets (and/or lexical items) in specific contexts.

It is worth discussing that the overall L1 disadvantage (found in the current study) in naming latencies across conditions is in line with the idea of inhibitory control, presumably at a different level from that typically seen in the switching literature (e.g., Christoffels et al., 2007). In other words, bilingual participants might be significantly slower in L1 naming as a result of global suppression of L1 in the presence of concurrent activation of L2. In addition to the domain-general aspect of language control, the finding may provide some evidence for language-specific control processes that are determined by the particular linguistic context-related factors. One plausible hypothesis, for example, is that the immersion context could provide a situation
where bilingual speakers adapt the control process to increase the baseline activation for the dominant language (English) according to the speaking context. Hence, language suppression versus activation could emerge depending on the context-induced expectation; the immersion context could still corroborate the persistent effect of domain-general inhibition on bilingual naming performance.

On the other hand, given that the immersion context may go beyond inhibition, I could introduce an alternative hypothesis, such that the context-induced expectation may alter the language control mechanism or processes specific to contextual needs. Adaptive control processes may operate in a certain context, so the dynamic nature of the control mechanisms can be seen at different levels of the processes, as argued by Abutalebi and Green (2013). A few studies have assumed this account of an adaptive control mechanism in bilingual language switching; yet, recent findings on bilingual advantage in cognitive control (i.e., performance monitoring and conflict monitoring) imply a possible link between the adaptive cognitive control and language selection mechanisms in bilingual individuals. Again, such adaptive control should be further studied in order to determine how different levels (loci) and/or types (manners) of language selection and control processes of the control mechanisms relate to a specific bilingual context. Thus, it will remain for subsequent research to further elucidate how different control processes cooperate depending on varying language contexts.

6.4. Open issues

While the current study addresses a number of important issues, some are still unresolved. Three points are discussed in this section, which future research should address since they are pertinent to the underlying mechanism of language control. First, although our findings suggest a role of (language set) activation in language selection, it is still understudied how the
language control processes may operate in conjunction with other cognitive functions, such as working memory updating that have been extensively studied in task switching. Interference control by activation and suppression has been mainly studied via the switching paradigm in which memory demands have not been incorporated; however, the relationship between proactive interference and working memory has been examined in task switching literature. Furthermore, at which linguistic levels, such as concept, lemma, or language schema/node, language control processes occur is less clear (see Declerck & Phillipp, 2015). For example, bilingual language control can be studied during connected speech production, which also taps grammatical processing (e.g., Gollan & Goldrick, 2016). By examining the locus of the control mechanism as well as the manner in which it operates, we would achieve a deeper understanding of the language control mechanism in bilingual speakers.

Second, the finding of a speed advantage for English in this study has been attributed to an immersion context, as the unique pattern of speed advantage observed for the dominant language reflected the role of a particular speaking context, independent of individual dominance. Therefore, immersion context is posited to account for the global effect of language activation versus suppression. This effect of immersion context remains to be further examined in terms of how much immersion experience is crucial to produce the effect, and which processes of the language control mechanism could drive the unique contribution of the immersion context to create a speed advantage. In addition, questions remain about how language profile information (e.g., language proficiency or language pair) would interact with bilingual’s language environments, further indicating or influencing how the two languages are represented or organized in the bilingual lexicon and then controlled during lexical selection. Therefore, it would be important to look at the relationship between the organization of lexical representations
and how they are controlled in different groups of bilingual individuals (e.g., foreign language users in non-immersion contexts) by utilizing multiple experimental measures (e.g., ERPs and Eye-tracking).

The last point relates to the relation between language-specific and domain-general control mechanisms because our data showed partial evidence for both. Prior studies have adopted different approaches to answer this question; we have learned, based on previous evidence, that there is some overlap between domains but also specific aspects of language control that differ from those for cognitive control (e.g., Branzi et al., 2016; Calabria et al., 2012; Weissberger et al., 2012). Further understanding of the control mechanism may also enhance our comprehension of bilinguals’ linguistic and non-linguistic abilities beyond the cognitive advantage and lexical retrieval among bilingual speakers. In sum, these important theoretical questions could help us understand language control on a different level by recognizing that language control occurs within the scope of all bilingual language processes and not only at the lexical-semantic level.

6.5. Conclusion

The current study examined bilingual language switching performance, asking whether high proficient bilingual speakers would be sensitive to task difficulty related to specific effects of interference. Furthermore, I was interested in the extent to which language control processes are shared across domains or specific to bilingual language production. In particular, I investigated how task-specific or language-specific factors affect language switching and language control in bilingual speakers. An effect of switch frequency was seen, indicating the unique role of task set activation as a shared aspect of the interference control mechanisms across domains. An effect of
language predominance in the stimulus sets was not observed, presumably due to a strong effect of speaking context on language activation among our bilingual participants.

The overall finding indicates a likely contribution of language immersion context to the nature of bilingual language control, as reflected by an English advantage in naming speed among the bilingual speakers. Furthermore, the diverse patterns of switching performance associated with degree of competition suggest that task set activation may also play a role in interference resolution. Further studies are necessary to delimit the scope of bilingual speakers’ control processes. To advance our understanding of the dynamic nature of bilingualism, individual linguistic features and language contextual effects on the control mechanism during language production should be thoroughly studied.
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