USING EVENT-RELATED POTENTIALS TO TRACK THE SCOPE AND
TIME COURSE OF INHIBITION DURING BILINGUAL SPEECH

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Abstract

Parallel activation of words in both the bilingual’s two languages has been observed even when bilinguals plan to speak a single word. This observation has sparked intense research on the issue of how bilinguals prevent the irrelevant language from intruding during speech production. The general consensus is that bilinguals exploit cognitive control to regulate the two languages during speech planning. Research demonstrates that, primarily, it is the dominant language (L1) that is regulated during speech planning to enable the less proficient language (L2) to be spoken. Recent research also suggests that regulation of the L1 can be performed via several mechanisms that vary in scope and time course. Evidence suggests that some mechanisms are short-lived, whereas others are long-lasting in time course. In addition, there appear to be mechanisms that restrict the access of specific words in the lexicon and some that affect the whole language itself, potentially producing extended consequences for the production system and for cognition more generally, that distinguish bilinguals from monolinguals. It is not yet known how mechanisms that exist for planning speech in the L2 manifest for L2 learners, for whom regulation of the L1 is anticipated to be even more crucial for enabling the L2 to be spoken. In addition, the issue of whether regulation during speech has consequences for L2 learners’ cognition is even less well understood. This dissertation aims to better understand the impact of L1 regulation for L2 learners’ speech planning as well as their cognitive functions. The innovation of this dissertation is to observe the processes that enable L2 production for learners who are limited in speaking the L2, by examining consequences of attempting to speak the L2 on the L1. The evidence presented here, although preliminary, suggests that the dominant language is affected when L2 learners speak the L2 and creates consequences for how learners engage cognitive control.
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Chapter 1: Background

1.1 Introduction.

If bilinguals were able to switch off one of their two languages, they would be able to function as if they were monolingual speakers of each language. An impressive body of research in the past twenty years shows that it is virtually impossible for bilinguals to avoid the activation of both languages, even when they intend to speak one language alone (e.g., Costa, 2005; Hermans, Bongaerts, De Bot, & Schreuder, 1998; Kroll, Bobb, & Wodniecka 2006). At the same time, other research has documented that bilinguals are able to code switch with one another, moving in and out of each language with fewer processing costs than might be expected (e.g., Kootstra, Van Hell, & Dijkstra, 2010; Myers-Scotton, 2002). Recent studies have also shown that relatively proficient bilinguals rarely produce words in the unintended language (e.g., Gollan, Sandoval, & Salmon, 2011), despite the apparent availability of candidates in both languages. The critical research question is then to understand how bilinguals select the language they intend to speak. The hypothesis is that the constant requirement to select one language in the face of competition from the other language creates a context for bilinguals to develop expertise that enhances cognitive control and produces domain general advantages for bilinguals in executive functions (e.g., Abutalebi & Green, 2007; Bialystok, Craik, Green, & Gollan, 2009). The non-selectivity of language processing and the consequences of bilingualism for cognition and brain function are well documented. What is not well understood is the selection mechanism itself.

A promising hypothesis that has begun to receive empirical support is that bilinguals accomplish language selection by inhibiting the more first or more dominant language (L1) to
speak the less dominant language (L2) (e.g., Levy, McVeigh, Marful, & Anderson, 2007; Linck, Kroll, & Sunderland, 2009; Philipp, Gade, & Koch, 2007). The constant requirement to inhibit the L1 to speak the L2 is hypothesized to underlie changes to the native language production system, creating long-lasting consequences for speech production that distinguish bilinguals from monolinguals. Furthermore, the constant recruitment of inhibitory control during bilingual speech planning is speculated to underlie changes in bilinguals’ ability to engage executive control. Thus, it appears that engaging inhibition during speech planning has consequences for language itself and consequences that generalize beyond language to affect other aspects of cognition.

The main goal of the current study is investigate the mechanisms that allow adult second language learners to speak the less dominant language. Second language (L2) learners are arguably even more challenged than proficient bilinguals when required to speak words in the L2. Therefore, a straightforward prediction is that learners rely on L1 regulation during speech planning like proficient bilinguals. However, this prediction has remained essentially speculative. Empirical investigations of how learners manage to speak words in a barely proficient language is critical for forming comprehensive accounts of the mechanisms that exist for planning speech as a bilingual. In addition, studies focusing on L2 learners are needed to shed light on the cognitive consequences of bilingualism at early stages of L2 development.

In recent years, the topic of bilingual speech planning has experienced an upsurge of research addressing more detailed questions about mechanisms of bilingual speech planning. Recent studies suggest that bilinguals do not exploit a single mechanism of inhibitory control during speech planning. When proficient bilinguals plan speech, they exploit multiple mechanisms of inhibition that differ with respect to many properties (e.g. Guo, Liu, Misra, &
Kroll, 2011). Despite recent evidence that has extended our understanding of mechanisms of speech planning further than ever before, there are still few studies that have investigated the mechanisms in place for L2 learners. The observation that L2 learners frequently fail to respond in the L2 has deterred research on this topic. Learners’ high omission rates, in particular, produce data that is unreliable and virtually impossible to interpret. Thus, until researchers develop approaches that offset learners’ weak proficiency speaking the L2, insight into mechanisms available for L2 planning at early stages of L2 development will remain elusive.

In the present dissertation, I aimed to identify the mechanisms of language regulation during L2 learners’ speech planning by focusing on the consequences of speaking the L2 on subsequent L1 speech production. A set of recent studies, using blocked speech production paradigms, have revealed that after speaking the L2 momentarily the L1 changes (e.g., Branzi, Martin, Abutalebi, & Costa, 2014; Misra, Guo, Bobb, & Kroll, 2012; Van Assche, Duyck, & Gollan, 2013). In such contexts, the L1 becomes less stable and automatic, strongly suggesting that L1 regulation had occurred while the L2 was spoken. The blocked production paradigm, then, is an ideal paradigm for examining processes involved in L2 speech for learners. The paradigm requires only a brief period of production in the L2, but the majority of task to be spoken in the L1. Because learners are highly skilled at speaking the dominant L1, L2 planning processes can be studied indirectly via the observed changes to the L1.

When proficient bilinguals speak the L1 after the L2 in blocked production tasks, there is evidence for extended consequences for the L1. For example, recent studies investigating the time course of L1 regulation have demonstrated long-lasting consequences for the L1 after speaking the L2 (e.g., Misra et al., 2012). In addition, recent studies investigating the scope of L1 regulation, the types of representations that are regulated during bilingual speech planning,
demonstrated that there are consequences that may generalize to affect the entire language itself (e.g., Branzi et al., 2014; Van Assche et al., 2013). In the present study, I ask how extended are the consequences of speaking the L2 on the L1 for learners. One aim of the study was to describe the scope of language regulation when L2 learners plan speech in the L1 after speaking the L2. When proficient bilinguals plan speech in the L1 after the L2, there has been evidence for multiple mechanisms that operate at different levels of scope. Thus, under conditions that have been shown to produce apparent language regulation it is not clear whether certain lexical domains are suppressed or whether one of the two languages is regulated more globally. If there is global regulation of all words in the L1 lexicon, it is possible that bilinguals’ L1 speech is generally suppressed relative to monolinguals’ L1 speech. This question has been asked with respect to processes engaged when proficient bilinguals plan speech in the L1 alone. The present dissertation investigated speech planned in the L1 alone for L2 learners to determine whether the L1 is affected by mechanisms of regulation even when learners are not required to speak the L2. An additional aim of the dissertation was to characterize the time course of language regulation. The goal of the dissertation is to evaluate processes that may be short lived, as evidenced in comprehension (e.g., Macizo, Bajo, Martin, 2010), and others that appear to be longer lasting, as evidenced in production (e.g., Linck et al., 2009).

The third aim of the dissertation was to examine the cognitive consequences of language regulation. A growing number of studies have demonstrated bilingual advantages that often reflect differences between bilinguals and monolinguals in the brain networks recruited for cognitive control. However, there is little evidence that provides a causal account of how language processing produces the observed neural differences or the arguably more fragile behavioral advantages. A recent hypothesis that is gaining increased support is that bilinguals
differ from monolinguals in their ability to modulate executive control as a consequence of their experience tuning control processes in the language domain (e.g., Green & Abutalebi, 2013; Morales, Yudes, Gomez-Ariza, and Bajo, 2015). By embedding a cognitive control task in a design that includes extended speech production over blocks, the proposed dissertation will simultaneously investigate changes to aspects of speech and changes to executive control that result from bilingualism. The innovation of this approach is that it captures in real time modulatory processes that are not easily observed in pure executive control measures, such as the Flanker task (e.g., Luk, Anderson, Craik, Crady, and Bialystok, 2010) or the Simon task (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004).

In this study, three experiments were conducted to examine the issues of scope, time course and the cognitive consequences of language control mechanisms supporting bilingual speech planning. Two experiments were conducted to address the scope and time course of language control in bilingual production using event-related potentials (ERPs) as the primary method. The third experiment used ERPs to investigate the consequences of the hypothesized inhibition during speech production for cognitive performance.

Before going into more detail within the introduction, first I will provide an overview of the structure of the dissertation. Chapter 1, the introduction, continues with a description of two models of bilingual lexical selection. Studies that have tested each model helped to initially develop hypotheses about mechanisms of control during speech planning. Therefore, the most relevant studies that highlight the crucial issues raised by each account are presented. The central question posed in the prior research, and revisited in this thesis, is whether there is a general framework that best characterizes the mechanisms of control during bilingual speech planning. Therefore, some thoughts will be given about each model’s ability to reconcile seemingly
contrasting results. Next, a critical analysis of how the initial pieces of evidence from the models tie in with recent evidence based on new production paradigms is given. It will be argued that the recent evidence favors an inhibitory language control mechanism, generally used whenever bilinguals plan speech. The role of inhibition as a mechanism of language control will be discussed with reference to behavioral, electrophysiological, and neuroimaging findings in language switching and blocked picture naming tasks. Importantly, the evidence reviewed will be used to introduce the hypothesis that there might not be a single mechanism of language control, be it inhibitory in nature or otherwise. Finally, the introduction describes how existing theories of bilingual language control might be extended to describe speech planning in L2 learners, a population for whom inhibition is assumed to be critical for planning speech.

In Chapter 2, a general overview of the dissertation study is presented. This study adopted a novel approach to investigate inhibitory mechanisms of speech planning in L2 learners. Because research investigating L2 speech planning in learners has traditionally been avoided, there is little direct evidence that can be used to predict how language control should manifest for L2 learners when they attempt to speak their L2. Chapter 2 introduces a framework for generating predictions regarding the mechanisms of language control during speech planning that exist for L2 learners based on the inhibitory account of bilingual speech planning. The current study, which considers issues of scope and time course of inhibition and the consequences of language regulation for L2 learners, is outlined. In Chapter 3, the general methods of the study are outlined. Chapter 4 presents Experiments 1 and 2, investigating the scope and time course of language regulation for L2 learners, in formatting for submission as a journal manuscript. Chapter 5, presents Experiment 3, investigating the cognitive consequences of language regulation for L2 learners, in formatting for submission as a journal manuscript.
Chapter 6 is a general conclusion, in which I discuss the mechanisms of language regulation observed when L2 learners plan speech, draw connections between the consequences of regulation observed for learners and proficient bilinguals, and expound on the link between language regulation processes exploited by L2 learners and cognitive control more broadly.

1.2 Models of Bilingual Language Selection.

There is abundant evidence demonstrating that both of the bilingual’s two languages are activated when the context requires only one (e.g., Colomé, 2001; Hermans et al., 1998; Hoshino & Kroll, 2008). If the empirical evidence for pervasive co-activation of two languages is an accurate reflection of the dynamics during bilingual speech planning, then it is remarkable that in everyday contexts bilinguals rarely make language selection errors. Investigations of speech production have shown that not only are alternatives in both languages active, but words can compete up to the point at which the phonology of a word is available (e.g., Costa et al., 2000). This means that not only are words in the unintended language activated, but they are on the tip of the bilingual’s tongue. However, such openness between the two languages during speech planning might not always be harmful for production. We also know that under some circumstances (e.g., fluent code switching), the language system must be flexible enough to allow parallel activation at minimal cost. A critical question then is what is the mechanism that allows such openness to persist during code-switching, on the one hand, but also effectively blocks the irrelevant language during contexts in which only a single language is to be spoken.

Two different accounts of bilingual language control have been proposed. Before describing the details of the alternative models, it may be useful to clarify the distinction between language activation and language selection. Virtually all of the models assume that there is
parallel activation of words in both of the bilingual’s two languages. The models differ with respect to assumptions they make about when in the process of speech planning bilinguals can attend to a single language and consequently, limit access to words in that language. What is counterintuitive is that one would not expect parallel activation of the two languages at all. Given that speakers typically begin planning to speak with an idea of what they want to say and the language in which they intend to say it, why should they activate the other language? The observation of parallel activation in bilingual production is at odds with our general intuitions about speaking. To speculate about the causes of parallel activation in speech contexts, there may be certain pragmatic reasons for parallel activation of two languages. One is that it may prepare bilinguals to alternate between the two languages as a means of maintaining fluency. Another reason is that it may help bilinguals recall autobiographical memories (which can be formed in different language contexts) to construct the spoken utterance (e.g., Schauf, Pavlenko, & Dewaele, 2003). Although the issue of why parallel activation occurs merits future scientific research, it is outside the scope of the present dissertation. For present purposes, we focus on the issue of language selection.

One class of models assumes that bilinguals cannot help but activate alternatives in both languages but that the intention to speak only one language effectively allows them to ignore the activity in the language not in use (e.g., Costa, Miozzo, & Caramazza 1999; Finkbeiner, Gollan, & Caramazza, 2006). This alternative proposes a kind of “mental fire wall” that enables the bilingual to selectively attend to the language in use and to ignore the activation of the other language. The other account assumes that alternatives in the other language are activated beyond a stage of initial conceptual access and that there is competition for selection both within and across languages. A late-acting mechanism is then hypothesized to accomplish selection of the
intended word in the target language. Although there are a range of possible mechanisms that might enable language selection, the most prominent alternative is the Inhibitory Control model (Green, 1998). The idea is that words in both languages become active but eventually words in the language not to be spoken are inhibited. I consider the evidence for each of these alternatives.

1.2.1 Mental Firewall Model

This language selective model (see Figure 1.1) requires that bilinguals are able to establish a clear means for identifying the language in use, in effect, a “mental fire wall.” On this view there may be activation of alternatives in the language not in use, but the selection mechanism for production is not affected by that activation. Costa, Miozzo, and Caramazza (1999) reported a study that has been taken as support for the mental firewall hypothesis. In a set of picture-word Stroop experiments, Catalan-Spanish bilinguals named pictures in their first language, L1 (Catalan), while ignoring distractor words in either L1 or in their second language, L2 (Spanish). The inclusion of translation distractors, words that share meaning in two languages, was a key manipulation that permitted a test of the mental firewall hypothesis. If words in the unintended language are considered for selection, then the name of the picture in the unintended language should be the most difficult distractor to process because it is precisely the word that should not be spoken. Contrary to that prediction, Costa et al. found facilitation in picture naming when the distractor was the translation equivalent of the word to be spoken. The converging meaning between the distractor and the word to be produced appeared to prime rather than interfere with the production of the correct picture name.
Figure 1.1 A schematic representation of the mental firewall account (adapted from La Heij, 2005).

Additional support for the mental firewall hypothesis has been reported in studies of tip-of-the-tongue (TOT) states in bilinguals. Tip-of-the-tongue states arise when speakers experience difficulty in retrieving the lexical form of a word from memory. Bilinguals have more TOTs than monolinguals (e.g., Gollan & Silverberg, 2001). For bilinguals, there may be possible interference between translation equivalents or other highly activated words in the unintended language that leads to difficulty in producing the intended word. However, for a word in the unintended language word to compete with the target word it must be known (i.e., be an item in the speaker’s vocabulary). Gollan and Acenas (2004) found evidence that bilinguals actually experienced more TOTs for words for which they did not know the translation equivalent than for words that they did know, suggesting that cross-language competition was not the basis of the bilingual TOT disadvantage. Instead, the results suggest that there may be other forms of control which are not necessarily inhibitory in nature (e.g., Hanulovà, Davidson & Indefrey, 2011; Kroll & Gollan, 2014). Mechanisms that result from differences in the overall frequency of L1 and L2
use, for example, have been hypothesized as alternatives that can explain the inhibitory-like patterns of TOTs during speech production (e.g., Gollan, Montoya, Cera, & Sandoval, 2008; Kroll & Gollan, 2014).

If bilinguals were able to divide their world in two, effectively creating a mental firewall, then we might predict that they would also be able to exploit cues that signal the presence of one language or the other. The available evidence suggests that even obvious cues to language membership are not easily used in this way (e.g., Hoshino & Kroll, 2008; Kroll et al., 2008; Schwartz & Kroll, 2006). Finding a means for differentiating the two languages from each other may be particularly difficult when the input itself lacks language-specific features, as in picture naming. Hoshino and Kroll (2008) asked whether differences in script would constrain the activation of the two languages in a picture naming task. They compared the performance of Japanese-English and Spanish-English bilinguals naming pictures in English, their L2. The pictures had names in the L1 that were either cognates in the two languages or distinct translation equivalents. In Japanese, it is possible to have only phonological overlap with English. In Spanish, both orthographic and phonological overlap is possible. Hoshino and Kroll found that both groups of bilinguals were faster to name pictures with cognate names than pictures with unique translations. The results suggest that a life-time of words in the two scripts was not sufficient to prevent the two languages from interacting in a production task. Other types of cues, including differences in language modality for bimodal bilinguals, also do not appear to be strong enough for preventing an unintended language from intruding during production. Generally, then, bilingual speech planning is characterized by the presence of competition during selection. The most parsimonious explanation to describe how bilinguals manage to speak
fluently in the absence of effective language cues is that there are processes that resolve cross-language activation once the competition arises (e.g., Kroll et al., 2006).

1.2.2 Competition for Selection Model

An alternative class of models assumes that all activated candidates compete for selection. A number of different proposals have attempted to account for the mechanism that eventually achieves selection, but a prominent model assumes that bilinguals resolve cross-language conflict through inhibition. The Inhibitory Control (IC) model (Green, 1998) proposes that words in the unintended language must eventually be suppressed to enable selection of words in the intended language. The IC model (see Figure 1.2) is an extension of a general inhibitory mechanism for regulating active tasks to the language production system. The model assumes that a task schema (i.e., for speaking in one language as opposed to the other) raises activation for representations in the intended language. Unlike other models of language selection, the IC model posits that the task schema suppresses activation of words that do not correspond with the intended language and this takes place after the unintended words are already active.

Figure 1.2. The Inhibitory Control (IC) model (adapted from Green, 1998).
Two additional assumptions of the IC model are worth noting. The model proposes that even though the words in the intended language are suppressed, they can interfere with lexical selection. The amount of inhibition required to suppress a word is hypothesized to be proportional to its level of activation, which leads to critical predictions concerning the relationship between language dominance and the amount of inhibition that might be called upon when speaking in each of the two languages. This model predicts more inhibition for words in the L1 when the L2 is the intended language. The asymmetry in inhibition of language representations is hypothesized to reflect the fact that when the languages are unbalanced in proficiency, the dominant language will usually have a higher level of activation than the less dominant language.

1.3 Evidence for Inhibition

1.3.1 Language switching paradigms

Early studies of language switching appeared to provide support for the IC model because they showed that there was an asymmetry in switch costs, with higher costs for the L1 following the L2 than the reverse (e.g., Meuter & Allport, 1999). The switch-cost asymmetry is commonly reported as increased response latencies on switch trials compared not non-switch trials that are greater when bilinguals switch from L2 to L1 than L1 to L2 (see Figures 1.3a and 1.3b).
Figure 1.3a. Naming latencies for Non-switch and Switch trials in both languages (adapted from Meuter & Allport, 1999). Figure 1.3b. Naming latencies for trials in mixed and blocked conditions for L1 and L2 (adapted from Kroll, Dijkstra, Janssen, & Schriefers, 2000).

The interpretation of the asymmetry is that the more dominant L1 requires inhibition during the planning of speech in the less dominant L2 so that subsequent speaking of L1 following L2 imposes a spillover cost to the L1 from an inhibited to an active state. Other studies of bilingual language switching have challenged this interpretation, arguing that it may only characterize the performance of less proficient bilinguals (e.g., Costa & Santesteban, 2004). However, even in studies not reporting a switch-cost asymmetry there are often slower processing times for the L1. The overall slowing of the L1 suggests that there may be general inhibition of the L1 when both languages are actively used. The idea that there are greater costs to the L1 in mixed language contexts has been indicated by other performance measures. When bilinguals are required to name pictures in a mixed and unpredictable fashion, L1 naming latencies are much slower than L2 latencies in the very same mixed context.

Although the evidence for asymmetries or increased costs associated with speaking the L1 observed in language-switching paradigms is highly consistent with inhibition, there are limitations that pose a challenge to the interpretation. As mentioned previously, the switching
asymmetry has not been replicated in all language-switching studies. For example, evidence for switching costs has not been found when bilinguals voluntarily switch between languages (e.g., Gollan & Ferreira, 2009). In addition, there is some evidence that supports the idea that processes that affect activation of the two languages, but that do not involve inhibition at all, can lead to switching asymmetries in language production tasks (e.g., Verhoef, Roelofs, & Chwilla, 2009). Another issue that limits the force of the switching asymmetry as evidence for inhibition is that differences in the time taken to speak in the two languages can reflect overall speed of processing differences between the L1 and L2.

1.3.2 ERP Investigations of Inhibition

Differences at the point at which response latencies are measured may be due to bilinguals’ reduced practice in producing speech sounds in the L2 relative to the L1. In effect, the switch cost asymmetry in speech production may reflect speed of processing differences for the two languages at the point of articulation. Because of this, measures that are sensitive to switching effects at a point in time prior to the speech act itself are critical for evaluating models of language selection. A number of ERP studies have investigated the time course of inhibition during language switching.

Event-related potentials, or ERPs, are electrophysiological brain responses that are time-locked to stimulus events. ERPs are a record of the electroencephalographic response measured from the surface of the scalp and reflect the summed activity of a large group of neurons (Coles, Gratton, & Fabiani, 2000). Standard changes in the ERP record in response to the onset of a cognitive event are referred to as ERP components. Typically, in language switching paradigms, the component of interest is the N200. The N200 (Figure 1.4) is a negative going peak in the waveform that appears between 250 and 350 ms after the onset of the stimulus and is usually
frontally distributed. It has been hypothesized to reflect response conflict or inhibition (e.g., Falkenstein, Hoormann, & Hohnsbein, 1999; Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003) because it has been found in tasks that require response suppression (such as Go/No-go tasks). Independent of correlates of inhibition in the speech act itself, information available in ERPs may provide insight into the time course of speech planning that will inform models of language selection.

Figure 1.4. An illustration of the N200 component when 50% of the trials in the task are No-Go trials (adapted from Nieuwenhuis, et al., 2003). The N200 is observed as the difference between the amplitude in the average waveforms from the Go condition and the No-Go condition (left side). The topographic map of voltage change (right side) illustrates the increased negativity that occurs at frontal electrode sites.

Many ERP studies have focused on the N200 effect that arises from local switches. Local switches are immediate changes in the response language and usually require languages to be alternated in close succession. This form of switching allows researchers to assess changes in activation that are associated with the requirement to update the response language. However, there are multiple forms of language switching that are possible and understanding the cognitive processes that support these forms of switching are equally important. In fact, if one considers
the manner in which bilinguals tend to use the two languages in everyday contexts, switches after extended production in a single language may characterize a larger portion of bilingual language switching behavior than word-to-word switches. Some ERP studies of bilingual language switching have investigated the pattern of inhibition that is evident when bilinguals engage in language mixing and also in alternation between languages that occurs after extended time speaking in one language alone. In most language switching studies, the “no-switch” trials occur in a mixed language context. A critical question then is whether there are effects of language mixing per se over and whether they are observed above the costs found for trial-to-trial switching.

Christoffels, Firk, and Schiller (2007) used ERPs to examine the effects of language switching and language mixing at the neural level and to determine whether the mixture of the two languages imposes processing costs apart from the immediate demands of language switching. A language switching cost is observed in the immediate context of a mixed language block and is measured as a switch from responding in Language A to responding in Language B. A language mixing cost is observed in the extended context of the task and is measured as the difference in performance when Language A is produced in a mixed language block versus a homogenous language block. Previous ERP studies of language switching have found evidence of local language switching effects. Jackson, Swainson, Cunnington, and Jackson (2001) found greater negativity for the N200 when non-switches rather than switches occurred in the L2. The reversed negative pattern observed for local switches is difficult to interpret given current theoretical assumptions about the manner in which languages interact during speech production. Because they did not include a comparison with pure language blocks, they were unable to assess
the effects of language mixing, so it is unclear how the N200 pattern observed for local switches fits in the context of more extended or global switches.

Christoffels et al. (2007) found a switching effect in the L1, but not the L2. Remarkably, when the language of production was the L1, non-switch trials elicited more negativity than switch trials in the L1. A tentative hypothesis explaining the reversed negativity is that the negativity results as a consequence of mixing the two languages. To facilitate production in the L2, the language that is typically less dominant for late bilinguals, the production system biases activation in favor of this language. This is one possible explanation for why maintaining the more dominant language for a non-switch trial induces more conflict than switching to the less dominant language.

Evidence from voluntary language switching tasks also corroborates this explanation. Gollan and Ferreira (2009) asked Spanish-English bilinguals to name pictures in either of their two languages but also perform some language switching throughout the task. When L2 dominant bilinguals had to mix the two languages, the L2 became slower and the L1, the weaker language in this case, was sped up. Gollan and Ferreira did not find any evidence for local switch costs, or costs at the immediate level of a switch from one language into the other using the voluntary switching paradigm. However, in the absence of local effects, global inhibitory effects on the dominant language were observed in the form of a language mixing cost. In sum, the results of both the ERP and behavioral studies of language switching appear to support the notion of two inhibitory mechanisms for language control.

For present purposes, I note that the evidence on language switching, both in behavioral and ERP studies, has not provided unequivocal support for either account of language selection. Recent studies using alternative paradigms to investigate bilingual production (e.g., Levy et al.,
2007; Linck et al., 2009; Philipp et al. 2007), have reported evidence that is more consistent with the inhibitory hypothesis. These recent studies, which exploit new paradigms beyond that of trial-to-trial language switching, increasingly favor an account of bilingual speech planning that exploits inhibition. The overarching motivation for using paradigms that use alternatives to the trial-by-trial switching paradigm appeals to the notion that greater evidence for inhibition is present in tasks that examine the extended effects of production in one language on the other (e.g., Linck et al., 2007). Moreover, the setup of these studies allow us to infer processes that are likely to occur in naturalistic speech contexts because they each include manipulations that allow the effects of the planning context to be observed.

1.3.3 Blocked picture naming paradigms

One commonsense notion is that naturalistic contexts in which bilinguals plan speech provide cues to language selection that may render inhibition irrelevant. In other words, the context in which speech planning occurs should be sufficient for biasing activation to one of the two languages. A strong case for inhibition could be argued if, given a context that strongly cues that only one of the bilingual’s two languages has to be produced, bilinguals still lack the ability to prevent competition between the two languages and demonstrate consequences of parallel activation. This is the logic that motivated Misra, Guo, Bobb and Kroll (2012) to use an extended blocked picture naming paradigm. Like the previous studies employing language switches, in Misra et al.’s (2012) task bilinguals were required to speak one of their two languages and then switch into the other. However, the language of picture naming was blocked so that many trials of picture naming occurred within a single language. The language switch occurred at the start of a new language block and the researchers hypothesized that switch costs may be present for the initial trials but not persist across the entirety of the new language block.
To measure the presence of inhibitory consequences from switching, they used repetitions of pictures across the initial language production blocks (pictures named in Language A) and the new language block (pictures named in Language B). If there was inhibition, then they did not expect to observe the typical pattern of facilitation for naming repeated pictures, but a reduction or full elimination of facilitation for naming repeated pictures. Like other studies that have examined language switching, ERPs were recorded during the picture naming to determine if inhibition could be observed in the moments leading up to speech production. In line with previous studies of language switching, Misra et al. (2012) observed asymmetric patterns of switching. Analysis of the ERPs showed that a group of bilinguals who initially named pictures in their L1 and switched into the L2 in the subsequent blocks were facilitated by naming pictures. This group demonstrated more positive going waves in response to naming repetitions in the L2 block. However, a group of bilinguals who named pictures initially in their L2 and subsequently switched into the L1 did not show facilitation. ERPs revealed an N200 and increased negativity that continued throughout the ERP epoch to repetitions in the L1 block. One important conclusion from the research conducted by Misra et al. is that bilinguals engage inhibition even in a context that strongly cues that only one language is to be spoken. This finding can be viewed as a challenge to the views of the mental firewall hypothesis and favoring the inhibitory accounts.

1.4 Evidence for multiple mechanisms of language regulation.

The evidence argued in favor of either the Inhibitory Control model or the mental firewall model is not easily accounted by either model alone, but can be accommodated by a view that acknowledges the presence of multiple mechanisms of language control when bilinguals plan speech. Importantly, different control mechanisms might be more or less clearly illustrated by focusing on certain tasks or even certain aspects within a single task (i.e., language switch costs).
Emerging evidence suggests that there are mechanisms exploited by bilinguals that differ in a number of properties. As mentioned previously, it is possible that some mechanisms are not inhibitory in nature, such as a mechanism that raises activation of the weaker language to bias its selection (e.g., Christoffels et al., 2007). While other mechanisms do appear inhibitory in nature, they may be either short-lived or they may last for a long time. The very fact that inhibitory mechanisms can differ with respect to each in at least one dimension, suggests that there may be a host of other properties that modulate the presence of inhibition in speech planning. Even the properties that are beginning to be considered have been documented in only a handful of empirical studies. For example, there is little extant research investigating both the time course and scope of inhibition in bilingual speech planning. Thus, there is little evidence that can address how different mechanisms that vary in time course and scope are related.

1.4.1 Mechanisms that differ in time course

It has been demonstrated that inhibition can last a long time, but it is not precisely clear how long these inhibitory processes extend in time. There may be momentary inhibition, such that bilinguals quickly recover their ability to speak the more dominant language, or long-lasting inhibition. In extreme cases, extended inhibitory consequences may lead to instances of L1 attrition. Blocked picture naming paradigms provide an experimental means for grappling with the issue of whether there are long-lasting consequences of parallel activation of two languages when bilinguals know the language of production in advance. If bilinguals use the context to select the language of production, then inhibition should only be present momentarily. A clear change in language context should enable bilinguals to recover a previously abandoned language quickly. The implication is that when the language of production can be anticipated, bilinguals engage short-lived mechanisms of control. Misra et al. (2012) found evidence that refuted this hypothesis.
Not only did Misra et al. discover that the intention to speak in a single language is not sufficient for eliminating competition for selection, they discovered that inhibition of words during planning was long-lasting.

Another form of inhibition may be long-lasting inhibition that extends beyond the immediate requirement to speak the L2. Frequent inhibition of the L1 may create far extending consequences, such that the bilingual’s L1 may appear globally suppressed all the time. In other words, the L1 might continually weaken and lose some of its dominance to accommodate speech planning in the weaker L2. If so, a prediction is that when monolinguals and bilinguals produce speech in the L1 alone the two groups will differ in native language production. Parker-Jones et al. (2011) conducted an fMRI study that investigated the neural correlates of speech planning when bilinguals and monolinguals performed a set of production tasks in the L1 alone. When bilinguals performed picture naming, they more strongly activated the planum temporale, superior temporal gyrus, pars opercularis and the pars triangularis than monolinguals. These regions have been implicated in the ability to control interference during verbal processing and articulatory processing, supporting the idea that bilinguals experience increased demands on speech during L1 only production, distinguishing them from monolinguals.

Some evidence suggesting a form of extremely long-lasting inhibition comes from the literature on immersion experience. For example, one study demonstrating long-lasting consequences of bilingualism suggests that immersion can change sensitivity to the grammatical features of the native language. Dussias and Sagarra (2008) conducted a study in which they demonstrated changes in sensitivity to L1 grammatical structure as a consequence of extended L2 immersion. Dussias and Sagarra (2008) showed that immersed bilinguals, who had been living in an L2-speaking country for several years, used L2 syntactic parsing strategies when reading L1
sentences for comprehension. The immersed bilinguals’ performance deviated from a group of monolinguals who did not speak an L2. In addition, a group of proficiency-matched, non-immersed bilinguals did not use L2 syntactic parsing strategies, suggesting that immersion was the source of the change to the syntactic parsing processes. Importantly, this finding suggested that L1 changes were possible in the domain of grammatical processing, an area that some argue is fairly entrenched. The point I wish to make is that L1 production is presumably, like grammatical processing, a domain that undergoes early entrenchment. What is remarkable about the change observed in Dussias and Sagarrà’s study is that the results imply that even highly-entrenched domains system can undergo large-scale changes as a consequence of acquiring an L2 later in life.

What is also striking is that the mechanisms that create such change appear to be a consequence of increasing L2 proficiency, suggesting that increasing accommodation of an L2 may prompt inhibition of the L1. Long-lasting mechanisms of L1 inhibition, then, may be responsible for large-scale changes that weaken the L1, make it less native-like, and effortful to use. Immersion might provide a naturalistic means for exploring how long-lasting mechanisms of inhibition lead to L1 change. However, such mechanisms need not be exclusive to immersion contexts. Given the constant requirement to select between L1 and L2, bilinguals might routinely exploit long-lasting mechanisms as a means for more effectively reducing potential interference from the L1. If so, we might expect bilinguals to demonstrate consequences of long-lasting mechanisms outside of immersion contexts. One prediction, then, is that long-lasting mechanisms of L1 control might distinguish bilinguals from monolinguals when they speak the L1 alone. In the present study, the focus is not on proficient bilinguals, for whom extended consequences might be expected. The focus is on L2 learners, for whom the requirement to select between languages during speech planning is clearly less frequent. However, if accommodating the L2 in the face of
a dominant L1 is the critical factor for L1 regulation, one might predict that the dominance associated with speaking the L1 would make regulation of the L1 even more critical for L2 speech planning. The prediction that follows, then, is that the consequences of L1 regulation should manifest more strongly at the early stages of L2 learning. Therefore, L2 learners are not expected to resemble monolingual speakers when they plan speech in their native language alone.

1.4.2 Mechanisms that differ in scope

Though long-lasting inhibition is a general means of resolving language competition during bilingual speech planning, there may be other alternatives. Importantly, these alternative mechanisms may vary in both time course and scope. Because bilinguals engage long-lasting inhibition it suggests that the mechanism of inhibition is global, suppressing the entire language itself. There is very little research that has directly manipulated the scope of inhibition. Instead, it has simply been inferred from long-lasting inhibitory effects that the scope of inhibition is also global. However, the scope of inhibition could be one of the bilingual’s two languages as a whole or a specific word not to be spoken, or some intermediate alternative (e.g., a word in a particular semantic category). Misra et al.’s (2012) study was able to examine the time course of inhibition, but its design did not permit a direct assessment of the scope of inhibition because the same items were named across blocks.

Guo et al.’s (2011) fMRI study provided one of the first pieces of evidence that there are mechanisms of inhibition that vary in scope. Guo et al. used fMRI to determine whether the neural basis for the blocked switching effect in the Misra et al. (2012) study was the same as the one engaged during mixed language picture naming. Results showed that the dorsal anterior cingulate cortex and pre-supramarginal gyrus were activated to a greater extent during mixed language naming and the dorsolateral prefrontal cortex and parietal cortex were more activated when the L1
followed the L2 in blocked naming. Thus, there was evidence for distinct networks of activation during mixed naming language blocks and single language blocks. The results fit nicely with the idea that there are at least two mechanisms that vary in scope, with one operating at the lexical-specific level (e.g., to support trial-by-trial switches) and another on the global level (e.g., to support mixed language naming). However, this study did not provide evidence that could rule out the possibility that mechanisms vary beyond the local and global levels. In addition, it is tempting to speculate that the distinct neural activity following blocked naming in the fMRI study reflects a mechanism of inhibition that is global and long-lasting, the time course of the mechanisms could not be directly inferred on the basis of the fMRI analyses.

To more directly examine the scope of inhibition, Rossi et al. (in preparation) conducted an fMRI study in which the items were not identical but drawn deliberately from different semantic categories. The logic was to enhance the separation of the two languages, not only by having the languages named in separate blocks, but also by having them associated with distinct semantic categories. In a first block of trials, English (L1) - Spanish (L2) bilinguals named pictures in English that were drawn from three different categories, all of which were animate (e.g., animals, body parts, vegetables). In a second block of trials, they named pictures only in Spanish that were drawn from three other categories, all of which were inanimate (e.g., clothing, furniture, kitchen items). The assignment of language to animate/inanimate categories was intended to create a “mental firewall” that would further cue participants to the language of naming. In six subsequent blocks, they named pictures in English that were mixtures of items drawn from the old items and categories presented in the first two blocks and new items from categories not previously named in either language.
Based on the previous studies, Rossi et al. (in preparation) predicted that there would be inhibition of the L1 following naming in the L2. Additionally, the design of this study permitted a set of specific predictions about the scope of inhibition. If inhibition occurs only for specific lexical items, then only the repetition of the same items should reveal a pattern consistent with inhibition. Items not previously named, but drawn from categories previously presented should not produce inhibition. If inhibition generalizes within a semantic domain, the new items drawn from previously named semantic categories might also be expected to produce inhibition. If inhibition is global and engages all of one language, then an inhibitory pattern might be expected even for new items in that language from categories that have not been previously named. Although the results of this study are preliminary, Rossi et al. found that bilinguals not only activated cognitive control regions while processing pictures that appeared during the initial blocks, they also did so while processing pictures from novel categories. These results provide initial evidence that the scope of inhibition during bilingual speech planning is global.

1.4.3 Mechanisms of language control for L2 Learners

There are few studies that have directly studied how speech planning is regulated at early stages of bilingualism for L2 learners. Instead, it has been simply assumed that due to the poor skill associated with speaking the L2, L2 learners must inhibit the L1 in order to speak the L2. However, Costa and Santesteban (2004) conducted a seminal study that compared speech planning in less and more proficient bilinguals. To be clear, the participants in their study were all proficient speakers of an L2. Thus, the less proficient bilinguals were not as unskilled as true L2 learners and the evidence cannot be assumed to map entirely to the processes that occur at the earliest stages of bilingualism. Recall that the mental firewall model was one of the few models existing at the time that made explicit predictions about the developmental trajectory of language regulation.
during bilingual speech planning. Therefore, the comparison between highly proficient and less proficient bilinguals did, at least, satisfy the broader goal of identifying how proficiency influences mechanisms of language control.

In their study, Costa and Santesteban (2004) compared the language switching performance of less proficient Spanish (L1)-Catalan (L2) and Korean (L1)-Spanish (L2) bilinguals to highly proficient Spanish (L1)-Catalan (L2) bilinguals. Participants named pictures in a local switching fashion. The researchers predicted that the less proficient bilinguals would demonstrate asymmetric switch costs, whereas highly proficient bilinguals would display symmetric switch costs. Results demonstrated that the highly proficient bilinguals displayed symmetric switch costs, whereas the L2 learners demonstrated asymmetric switch costs. One explanation for the data is that bilinguals who are not balanced in L1 and L2 proficiency inhibit the L1 to speak the L2. The asymmetry occurs because there is less inhibition required for speaking the L2 compared to the L1. Highly proficient bilinguals do not have to engage additional inhibitory processes for the sake of planning speech in the L2, because they are equally skilled at speaking the L1 and the L2. Thus, when proficient bilinguals perform language switching, the costs are symmetric. These findings were interpreted as nearly irrefutable evidence for the mental firewall models’ claim that inhibition was only relevant for less proficient bilinguals. However, there was another aspect of Costa and Santesteban’s (2004) data suggesting that inhibition was present even for the highly proficient bilinguals. Although the highly proficient bilinguals did not demonstrate switch cost asymmetries, they did demonstrate a mixing cost. The highly proficient Spanish-Catalan bilinguals were overall slower to speak their L1 than their L2 when languages were mixed. What was once a paradoxical finding, namely that highly proficient bilinguals become much slower to produce their L1 than their L2, could be considered as evidence that inhibition occurs during speech planning regardless
of a speaker’s proficiency level. Critically, then, the prediction for learners is that they should engage inhibition. In line with Costa and Santesteban’s evidence on language switching, L2 learners should engage inhibition more strongly than proficient bilinguals.

Linck, Kroll, and Sunderman (2009) conducted one of the few studies that directly examined the consequences of immersion experience on the L1 at the early stages of bilingualism. Linck et al. tested classroom learners of Spanish who were immersed in Spain on translation recognition of L1 and L2 words and verbal fluency in the L1 and L2. They hypothesized that immersion experience would provide positive effects on L2 proficiency while learners were immersed. They also predicted that immersion might promote inhibition of the L1 for L2 learners. In other words, gains in L2 proficiency in immersion contexts might be mediated by inhibition of the L1. To test these predictions, they compared immersed learners’ performance to a group of Spanish learners who remained in the L1 environment. Previous studies have demonstrated that non-immersed L2 learners activate the L1 translation equivalent of L2 words when processing L2 words for meaning (e.g., Kroll & Stewart, 1994; Sunderman & Kroll, 2006). Linck et al. hypothesized that if the immersed learners inhibited their L1, they would be less sensitive to the L1 lexical distractors than a group of non-immersed learners. They also predicted that inhibition of the L1 would cause the L2 learners to produce fewer L1 exemplars in the verbal fluency task than non-immersed learners. Results demonstrated evidence supporting inhibition. Immersed learners were significantly faster to reject the form distractor than non-immersed learners in the translation recognition task and produced fewer L1 exemplars than the non-immersed learners during verbal fluency (see Figures 1.5a and 1.5b).
Figure 1.5a. Magnitude of distractor interference for Lexical and Semantic trials by immersed and classroom learners (adapted from Linck, Sunderman, & Kroll, 2009). Figure 1.5b. Mean number of exemplars produced in L1 and L2 by immersed and classroom learners (adapted from Linck, Sunderman, & Kroll, 2009).

Critically, one would expect that when the immersed learners returned to the L1 environment the L1 was no longer suppressed. However, when a subset of the immersed learners were retested after several months in the L1 environment they continued to show insensitivity to the form related distractors on the translation recognition task (see Figure 1.6). These data suggest that not only do learners appear to inhibit the L1, but are may be long-lasting consequences of inhibition for learners’ L1, such that the L1 does not immediately recover.
Evidence from Linck et al.’s (2009) study suggests that there are extensive consequences of speaking an L2 on the L1 for L2 learners. This evidence upholds the predictions of the Inhibitory Control model (Green, 1998). According to this model, the more dominant L1 has greater control over speech planning, competing with the L2 whenever the weaker language must be spoken. To control the L1, the prediction is that learners should rely on considerable L1 inhibition. The observation that the highly skilled L1 loses some of its dominance, even for learners, is evidence for the presence of considerable inhibition during speech planning. However, this study was not able to determine whether consequences observed for L2 learners’ speech planning were extended in the immediate time course of speech planning, as demonstrated by Misra et al. (2012). In addition, the results of Linck et al.’s study could not clarify the scope of language regulation for L2 learners. Given the robust effects on the L1 shown by learners in Linck et al.’s study, one might expect that inhibition was global in scope. However, one might also imagine that the rather limited experience that L2 learners have speaking the L2 would mean that regulation is more restrictive. In addition, it is unclear whether L1 regulation when L2 learners plan speech only occurs when learners are immediately required to speak the L2. Finally, it is not clear whether L2 learners experience cognitive consequences of regulation during speech planning. Taken together, there are critical gaps in knowledge concerning mechanisms of L2 speech planning. The goal of the current dissertation is to inform existing models of bilingual speech planning by studying L2 learners production using the same paradigms as those used to study proficient bilingual speakers.
Chapter 2: Overview of the present study

2.1 Goals of the study.

We now know that even highly proficient bilinguals must regulate their L1 for sake of speech planning. The main question addressed in this dissertation pertains to how L2 learners at the early stages of L2 development control the two languages during speech planning. Mechanisms of language regulation should be even more critical for L2 learners, who are arguably in a much more challenged position than proficient bilinguals when attempting to speak the L2 (e.g., Costa & Santesteban, 2004). This dissertation study used a novel approach to examine the mechanisms of language control that support speech planning in L2 learners. Most past research on L2 learners has avoided examining speech production in learners since their difficulty speaking the L2 generates noisy data that are difficult to interpret. The experiments reported within this dissertation borrowed the logic of recent studies of proficient speakers, focusing on the consequences of speaking the L2 for the L1. This approach serves as a means for indirectly studying the processes that enable speech in the L2 (e.g., Misra et al., 2012, Branzi, Martin, Abutalebi, & Costa, 2014). Because learners are highly skilled in producing the L1, the focus on L1 enables a window into these regulatory mechanisms at even very early stages of L2 learning. This approach also facilitates comparisons between the results observed for the L2 learners and the larger set of results that pertain to speech planning in highly proficient bilinguals. Additionally, the current study aimed to describe the scope and the time course properties of the mechanisms of control that exist for L2 learners when they plan speech. Previous research demonstrates that proficient bilinguals exploit long-lasting mechanisms of inhibition. This evidence also suggests that there is a relationship
between the scope and time course of inhibition observed during speech planning, such that inhibition that is long-lasting is also global in scope. In the present dissertation I asked whether, like highly proficient bilinguals, learners demonstrate evidence of long-lasting and global inhibition.

Another goal of this dissertation was to determine whether or not there are enduring consequences of speaking the L2 that manifest on the L1 even when the L2 is not immediately spoken. To this end, I exploited the extended blocked picture naming paradigm to examine consequences for L1 speech planning when L2 learners speak only their L1. If there were consequences that exist for the L1, even when it is the only language spoken, L2 learners should not resemble monolinguals in their L1 production. The prediction was that even at this relatively early stage of bilingualism, L2 learners might recruit distinct processes for speaking the L1 compared to monolinguals.

Finally, this dissertation investigated a set of claims about the relationship between domain-general cognitive control and the negotiation of language conflict during speech planning. When tested on tasks that measure domain-general executive functions (such as the Simon task or the Erikson Flanker task), bilinguals outperform monolinguals (Bialystok, Craik, Klein, & Viswanathan, 2004; Costa, Hernández, & Sebastián-Gallés, 2008; Martin-Rhee & Bialystok, 2008). Some researchers speculate that bilinguals’ experience negotiating competition between languages confers them with advantages in executive control (Kroll & Bialystok, 2013). There are many studies that have replicated the bilingual advantage in executive control (e.g., Blumenfield & Marian, 2011, Colzato, Bajo, Van den Wildenberg, Paolieri, Nieuwenhuis, La Heij, & Hommel, 2008; Prior & Gollan, 2011). However, there are additional studies that have failed to replicate the so-called bilingual advantages. In truth, the term “advantages” may be have been coined
inaccurately since bilinguals do not always outperform monolinguals on executive control tasks. What does appear to be a hallmark of bilingualism, however, is that bilinguals appear to respond to cues within task that vary in executive control tasks more flexibly than monolinguals (e.g., Morales, Yudes, Gomez-Ariza, and Bajo, 2015). Interestingly, this skill may be one of the most essential bilingual changes in cognition since responding flexibly to cues characterizes the nature by which bilinguals become proficient users of two languages (e.g., Green & Abutalebi, 2013). A critical question, then, is whether modulation of cognitive control during speech planning comes to bear on how bilinguals perform executive control tasks.

It was predicted that developing expertise in regulation would be critical for enabling L2 learners to speak the L2 and thus, L2 learners would demonstrate differences when compared to monolinguals on an executive control task. Specifically, there may be a special role for inhibition whenever L2 learners plan speech, fundamentally altering L2 learners’ cognition from that of a monolingual. That is, mechanisms of inhibition may develop due to the constant requirement to negotiate competition between languages every time learners attempt to speak the L2. It is important to consider that although L2 learners are acquiring an L2 and differ from monolinguals in that they face cross-language activation, they still are required to speak the L1 to the same extent as monolinguals. That is, there may be limitations on how extended inhibition manifests for learners since inhibiting the L1 all the time would be costly in an L1 dominant environment. Inhibiting the L1 for the sake of speaking the L2 would be costly if learners did not develop a way to recover from inhibition when the context requires the L1 to be spoken. One might then predict that bilinguals develop an advantage at recovering from inhibition. The second experiment within this study examines monolinguals’ and L2 learners’ performance in a Go/No-go picture naming task to examine whether there are differences in the extent to which monolinguals and L2 learners
engage inhibition and whether recovery from inhibition can be caught on the fly during speech planning itself.

Before presenting Experiments 1 - 3, I now turn to a general overview of the experiments and the predictions for each experiment.

**2.2 Overview of the experiments and predictions.**

To investigate L2 speech planning processes, Experiment 1 adopted the approach used by Misra et al.’s (2012) to study the consequences of speaking the L2 on subsequent L1 production. Learners are expected to require lots of cognitive resources to speak their weaker L2. Therefore, one would predict that greater consequences of speaking the L2 on for L1 learners than proficient bilinguals. Specifically, the dominant L1 might require regulation in the form of inhibition in order to prevent it from being spoken when the L2 is required for production. Previous studies have demonstrated evidence for consequences of speaking the L2 on the L1 that reflect the presence of inhibitory processes, but these studies have not been able to characterize the scope and time course of the consequences and how they relate to one another. In order to characterize specific aspects of the inhibitory mechanisms involved in L2 learners’ speech planning, the design of the Misra et al. study was modified. First, picture naming was performed over eight blocks to permit a more fine-grained analysis of the time course of language regulation. That is, the design mirrored Rossi et al. (in preparation). Like Rossi et al.’s study, the design was modified to include novel pictures along with repetitions. Repetitions were included that were literal repetitions of the pictures named in the initial L1 and L2 blocks and repetitions of the categories named in the first blocks of L1 and L2 naming. This manipulation was included to address whether the scope of language regulation generalized beyond specific words to influence a cohort of semantically related words, or even the entire language itself. ERPs were used to ask whether the first moments of planning speech are
affected by the same semantic and temporal factors that appear to influence the patterns of brain activity observed in the fMRI record. Because there may well be multiple factors that contribute to the hypothesized inhibition, including processes that are more time-limited than fMRI or behavioral methods can detect, the ERP record under these conditions may reveal early or momentary aspects of inhibition that would otherwise go unnoticed.

The design of the present study (see Table 1) allowed for a rich set of predictions to be made about the scope of inhibition, the time course of inhibition, and the immediate consequences of speaking the L2 on the L1. As mentioned previously, inhibitory accounts of speech planning (e.g., Green, 1998) predict that learners should show large consequences of speaking the L2 on the L1. Another set of critical questions concern how long these effects last in time and how extensive these effects are in scope. Misra et al. (2012) found evidence that inhibition was long-lasting in the immediate time course of speech planning and that inhibition extended across many blocks in the task.

Based upon the principles in Green’s (1998) Inhibitory Control model, inhibition may be long-lasting because whenever bilinguals switch languages they must reconfigure the language of production (see Rogers & Monsell (1995) for a similar explanation of domain general switch costs). One way bilinguals could reconfigure the language of production is by using top-down control to select the language they intend to speak. Despite the use of top-down control, successful reconfiguration of the language of production may require a very long amount of time because recovery is influenced by additional factors. These factors include residual inhibition of the now-relevant language (e.g., Mayr & Keele, 2000) and persistent interference from associations between the stimulus and the now-irrelevant language (e.g., Wazak, Hommel, & Allport, 2003). What is critical to understand for the present purposes, though, is that if we assume that residual
inhibition/persistent interference delay reconfiguration of intended language, the delay would affect learners just as much as they affect highly proficient bilinguals. If anything, because L2 learners speak a weaker L2 that prompts greater inhibition of the L1, reconfiguration, and hence the time course of inhibition, should be more extended for L2 learners.

In addition, Experiments 1 and 2 included conditions to allow insight into whether there are enduring consequences of speaking an L2 that exists even when L2 learners are only required to speak their L1. It is rather counterintuitive that L2 learners would demonstrate evidence for L1 inhibition when the context only requires them to speak their L1. L2 learners do not possess as much skill speaking their L2 as proficient bilinguals, and so it is possible that experience speaking the L2 does not influence speech planned in the L1 alone. However, some research evidence supports the notion that L1 inhibition is present even in the very early stages of L2 learning (e.g. Kroll, Michael, Tokowicz, & Dufour, 2002). Kroll, Michael, Tokowicz, and Dufour (2002) asked a group of less and more proficient L2 learners to name words aloud in their L1 or their L2. An expected effect of proficiency was found demonstrating that the less proficient learners were slower to name aloud L2 words than the more proficient learners. An unexpected effect of proficiency was observed for naming L1 words aloud. Less proficient learners were slower to name words in English (L1) than the more proficient learners, suggesting that the early stages of bilingualism are characterized by a period of L1 inhibition. In light of these findings, there might be evidence for enduring effects of their history speaking an L2 on L1 speech planning processes. When L2 learners’ and monolinguals’ L1 speech planning processes are compared one would expect differences. However, in the present dissertation L2 learners were still highly L1 dominant at the time of testing and expected to resemble monolinguals in L1 only production.
In each of the experiments, ERPs were used to provide information about how the earliest moments of processing were influenced by consequences of L2 learning. The general approach of combining behavioral measures with ERPs might be especially useful since L2 learners might not be that sensitive to the influence of the emerging L2 system. Prior studies suggest that ERP measures can be more sensitive to the developmental trajectory of L2 learning than behavioral measures. For example, previous investigations have shown that ERP measures are highly sensitive to the early consequences of L2 learning (e.g., McLaughlin, Ousterhout & Kim, 2004 Tokowicz & MacWhinney, 2005). In the present dissertation study, it is possible that the ERPs would reveal stronger evidence for consequences than the behavioral measures. In particular, the combined use of behavioral methods and ERPs might be much more sensitive to the enduring consequences of L2 learning than the behavioral measures alone.

The main hypothesis tested in Experiment 3 concerns whether regulation of the L1 via inhibition is a feature that distinguishes L2 learners from monolinguals and creates consequences for executive processes. In order to address this question, the design of the extended blocked paradigm was modified to include Go/No-go picture naming. The prediction was that when L2 learners speak the L1 after the L2, there will be evidence for inhibition of the L1. This inhibition is expected to produce downstream consequences for learners’ performance during Go/No-go picture naming since language control occurred while speaking the L2. The logic behind including Go/No-go conditions is to develop an additional means of tracking inhibition over time and is also based on a study conducted by Blumenfeld and Marian (2011). Blumenfeld and Marian (2011) asked monolinguals and bilinguals to listen to an aurally presented target word and then identify the location of the target within a four quadrant visual array. A distractor object that overlapped in phonology with the target object was included in the array in order to
introduce competition. On the subsequent trial, a response had to be made to the quadrant that previously contained the distractor. The idea was that if the distractor location had been inhibited to enable selection of the target, then participants would be slower to respond on the subsequent trial. Essentially this is a form of negative priming.

Figure 2.1. A schematic of Blumenfeld & Marian’s (2011) task. The top portion of the figure displays the first trial in the sequence of prime and probe trials. The target priming “plug” is responded to on this trial and on the second trial button response corresponds with the location where the competitor “plug” was.

Their results showed that monolinguals were slower to respond on competitor priming probe trials (“plug”) compared to control trials without phonological competition (for example, when the competitor was “ant”), suggesting that they inhibited the location of the distractor stimulus. However, bilinguals were no slower identifying the location of a stimulus on the subsequent trial when it previously contained the competitor than when it previously contained a control. These findings suggest bilinguals disengage from inhibition earlier than monolinguals.
In Experiment 3, a similar negative priming condition will exist when participants are required to inhibit pictures that had initially been named in the first phase of the task. As in Blumenfeld and Marian’s (2011) study, which used eye-tracking to follow the earliest moments of processing during, ERPs will be used as a measure for localizing the timing of recovery on an immediate scale. Critically, it is hypothesized that components of inhibition in the Go/No-go task (e.g., the N200 and P300 components) may undergo additional modulation as a consequence of speaking the L2. If so, monolinguals and L2 learners will not resemble each other in Go/No-go responses. Critically, while consequences of inhibiting the L1 are expected to impact Go/No-go performance, learners should recover from L1 inhibition within the span of the task. Thus, the extended blocked design of the proposed experiment will also shed light on recovery from inhibition within a larger timeframe.

Table 1

*Overview of Experiments in Present Research*

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Groups and Conditions</th>
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<tbody>
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<td>1.  Time course and scope</td>
<td>Learners Name English After Spanish</td>
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<tr>
<td>2.  Time course and scope</td>
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</tr>
</tbody>
</table>
| 3.  Catching inhibitory control | Learners Name English After Spanish  
                           | Monolinguals Name English Only       |

In addition to the main blocked picture naming tasks, participants from Experiments 1-2 performed a set of cognitive tasks to assess individual differences in executive control, memory, and language. These set of individual difference measures were collected in a separate session prior to the session involving picture naming. In Chapter 3, the materials, participants, and tasks are explained.
Chapter 3: General Method

3.1 Participants.

All participants were native speakers of English recruited from the Penn State University (University Park, PA). Monolingual speakers of English who had minimal exposure to a foreign language in the past and who were not actively taking courses in a foreign language at the time of testing were recruited. Native English speakers who had intermediate proficiency in L2 Spanish were also recruited for the L2 learner conditions. Additional recruitment criteria for the L2 learners were that they had taken 400-level coursework in Spanish at Penn State University or had recent study abroad experience in a Spanish speaking country. Two groups of intermediate Spanish L2 learners were recruited for Experiments 1 and 2, which aimed to examine the scope and time course of inhibition during speech planning. Nineteen participants were randomly assigned to the L1 alone condition and 18 participants were assigned to the L1-after-L2 condition. Eighteen monolinguals participated in Experiment 2, which focused on the enduring consequences of L2 learning for L1 speech planning.

For Experiment 3, which aimed to track inhibitory processes during speech planning as it occurs on-the-fly, two additional groups of Spanish learners and monolinguals were recruited. Eighteen Spanish learners recruited from the same pool as participants from Experiments 1 and 2 named pictures in the L1 after the L2. Eighteen monolingual speakers of English who were matched on age, L1 proficiency and cognitive ability with the L2 learners also participated in the study.
3.2 Materials.

3.2.1 Language history questionnaire

A questionnaire was used in order to collect data on the participants’ language background. Questions regarded the participants’ age, self-reported L1 and L2 proficiency (in reading, writing, speaking and listening skills), amount of L2 study, and other linguistic experience factors such as amount of time spent abroad in an L2 context and whether the L2 was spoken at home.

3.2.2 Handedness inventory

Prior to testing all participants were screened for handedness to ensure that they were right-hand dominant. Participants were given a form that asked them to indicate whether they preferred to use the left or right hand to perform a number of manual activities (e.g., writing, shoveling, using a racquet, etc.). Any participant whose ratings indicated that they had equal preference for both hands or a preference for the left hand was excluded from the study. In addition, this form asked participants to answer questions regarding family history of left-handedness, history of reading/speech disorders, and neurological impairments.

3.2.3 English lexical decision

A lexical decision task in English was used as an assessment of L1 proficiency. Given that all participants were English dominant we additionally considered it as a proxy of English vocabulary size. Previous research has shown that it is a reliable test of vocabulary size (e.g., Huibregtse, Admiraal, & Maera, 2002).

Materials

Fifty-six English words and 56 pseudo-homophones were presented during the English lexical decision task. The words were selected from a normed database (Azuma and Van Order, 1997) such that they varied in the number of different meanings and the degree relatedness between
its different meanings. Pseudo-homophones included nonwords that sound like real words (e.g., panzy). Participants viewed one of four pseudorandomized lists, seeing no more than three items from the same condition in a row.

Procedure

Participants received 10 practice trials before beginning the actual experimental run. They were instructed to respond as quickly and accurately as possible to words (by pressing the C button on the keyboard) and nonwords (by pressing the M button on the keyboard). Participants first saw a fixation for 500 milliseconds (ms) at the center of the computer screen. After the fixation disappeared, the target stimulus remained on the screen until a response was made. Then a new fixation appeared for 500 ms, cueing the next trial.

Data Analyses

Responses were filtered to include only correct items with RTs within 200 and 2000 ms, and then additionally cleaned to remove responses greater than 2.5 standard deviations of the mean RT. The mean RT and mean accuracy were computed for each participant. D’ was also calculated to provide a measure that accounted for potential response biases.

3.2.4 Spanish lexical decision

Materials

Fifty words and nonwords were presented during the Spanish lexical decision task. Half of the words were cognates in Spanish and English (e.g., bicicleta-bicycle) and half were noncognates (e.g., bolsa-purse). Nonwords were pseudo-words that contained phonotactically legal sequences of letters in Spanish. Two counterbalanced lists were created that contained two blocks of items and pseudorandomized the order of word and nonword presentation.

Procedure
Participants received 10 practice trials before the actual experimental run. They were instructed to respond as quickly and accurately as possible to words (by pressing the first button on the serial button box, Psychological Software Tools, Inc.) and nonwords (by pressing the last button on the serial button box). Participants first saw a fixation for 500 milliseconds, the target stimulus for up to 2000 milliseconds, and a blank screen for 500 milliseconds, before the next trial. The target stimulus remained on the screen until participants made their response.

Data Analyses

Responses were filtered to include only correct items with RTs within 300 and 3000 ms, and then additionally cleaned to remove responses greater than 2.5 standard deviations of the mean RT. The mean RT and mean accuracy were computed for each participant. D’ was also calculated to provide a measure that accounted for potential response biases.

3.2.5 Operation Span

The operation span was used to assess individual differences in working memory capacity. This task was chosen over other span tasks (such as reading span or listening span) because it appears to predict the efficiency of language processing as well as reading and speaking span measures, while also minimizing the contribution of language-specific processing (Turner & Engle, 1989).

Materials

A total of 60 equations and English words were presented in this task. Word stimuli came from Tokowicz, Michael, & Kroll (2004). Half of the math equations were correct or incorrect.

Procedure

Participants were instructed that they would solve math equations while simultaneously storing English words in memory. Each trial began with a fixation sign (+), presented in the center
of the screen for 1000 ms. Next, a simple algebraic equation (e.g., \((4*2)-2=2\)) appeared, on which participants judged the accuracy of the solution to the equation. Participants were told to respond as quickly and accurately as possible to the equation by pressing yes when it was correct (D button on the keyboard) or no when it was incorrect (K button on the keyboard). The equation remained on the screen until their response or up to 3750 ms. Then an English word appeared for 1250 ms and was followed by another fixation that indicated the beginning of a new equation. This sequence of events repeated until the complete set of equations and words was presented. After the complete set of equations and words was presented, the word “RECALL” appeared on the screen to prompt the participant to use the keyboard to type in all the words they had seen during the set. Participants were instructed that they did not have to type the words in the exact order in which they were presented, but they would receive an error for typing the last word of the set as their first response. They were instructed to begin the next set of words and equations by pressing the ESCAPE button. Set sizes ranged from 2 to 6 equations and words and set size incrementally increased as the task progressed.

There were always three sets of the same size before the set size increased to the next level (e.g., increasing from 3 to four equation/word pairs). Participants received two practice trials before the actual experimental trials.

Data Analyses

The mean RTs for correct judgments were calculated separately for “yes” and “no” stimuli. RTs that were 2.5 standard deviations above or below the mean were identified as outliers and excluded from the analysis. I then counted the number of words that were recalled correctly among correct responses to the equation judgment. This number was used as an index of the participant’s operation span.
3.2.6 Flanker task

Different components of cognitive control have been implicated as potential mechanisms that allow bilinguals to control their two languages. The Flanker task enables more precise predictions to be made about the nature of the inhibitory control mechanisms exploited by bilinguals because it isolates response inhibition from interference suppression (e.g., Luk, Anderson, Craik, Crady, and Bialystok, 2010). In addition, it has conditions that probe the ability to exploit exogenous cues. Therefore, in the present study, the Flanker task was used to isolate the precise components of cognitive control that L2 learners may have expertise in.

Materials

Pictures of shape sequences served as the materials. Each condition of the task (Control, Congruent, Incongruent, Go, and No-go) relied on pictures containing a particular arrangement of shapes. Control pictures contained a single red (target) arrow. Congruent pictures included a sequence of black arrows pointing in the same direction (left or right) as the red target arrow. Incongruent pictures included a sequence of black arrows pointing in the opposite direction as the red target arrow. Go trials contained a red target arrow embedded among black “diamond” shapes. No-go trials contained a red triangle surrounded by black “X” shapes.

Procedure

The task was adapted from Luk, Anderson, Craik, Crady, and Bialystok (2010). Participants were instructed that they had to respond to the red target arrow by indicating the direction in which it pointed. When the arrow pointed left, they pressed the leftmost button on the S-R button box. When the arrow pointed right, they pressed the rightmost button on the S-R button box. Participants were told that they would perform a series of different flanker sections, in which they sometimes saw the target arrow surrounded by other shapes. First, they had to respond to the
direction of arrows within a Control section. Next, they were told to ignore the distractor information during a Congruent and Incongruent section and simply respond to direction of the target. On the Go/No-go section they were instructed to pay attention to the surrounding shapes and only respond when the surrounding shapes were diamonds. They had to withhold their responses when the surrounding shapes were “X”s. Then participants completed a “Mixed” section during which a combination of Control, Congruent, Incongruent, and Go/No-go trials was presented. Finally, the Control, Congruent/Incongruent, Mixed, and Go/No-go sections were repeated individually. The order in which the repeated sections appeared was counterbalanced.

A fixation appeared at the center of the screen for a variable duration (range = 700 to 2700 ms, 500 ms increments). The flanker picture was shown for 1000 ms, followed by a 300 ms blank screen.

Data Analyses

Responses were filtered to include only correct responses with RTs within 50 and 1500 ms. After this step, only responses within 2.5 standard deviations of the mean were kept for analysis. Mean RT and accuracy was calculated for Congruent, Control, Go, and Incongruent Trials.

3.2.7 Task switching

One key difference between monolingual and bilingual language use is that only bilinguals have to switch back and forth between two sets of linguistic representations on a regular basis. I tested both groups on the Task switching task to determine whether L2 learners show advantages in the ability to switch between mental sets.
Materials

Materials included pictures of a shape that was paired and pictures of a non-linguistic cue. Circles and triangles that were colored green or red appeared as the shapes. The color cue was a color gradient and the cue for shape was a row of smaller black shapes.

Procedure

The procedure was adapted from Prior and MacWhinney (2010). Participants were told that they would perform a switching task. First, participants performed the color and shape task in single-task conditions. For the color-only task, participants had to use their left hand to indicate whether the shape was green or red. Participants pressed the “Z” key with their left middle finger when it was red and the “C” key with their left index finger when it was green. For the shape-only task, participants were instructed to press the “,” key with their right index finger when it was a circle and the “/” key with their right middle finger. The order in which the single-task conditions appeared was counterbalanced across participants. Next, they performed the mixed-task blocks. The response keys for the single-tasks and mixed-tasks remained the same. Stickers were used to label the response keys for color and shapes (filled in with black ink).

There were 8 practice trials and 36 experimental trials within each single-task block. Participants completed 16 mixed-task practice trials. In total, there were 3 mixed-task blocks consisting of 48 trials apiece. Half of the trials were switch trials and half were non-switch. Similarly, there were equal color and shape trials in the mixed blocks. In addition, following the last mixed block, the participants performed two additional single-task blocks.

Each trial began with a fixation (+) presented for 350 ms, followed by a 150 ms black screen. The task cue then appeared for 250 ms. The cue remained on the screen and then the target appeared beneath it. The cue and target remained on the screen until the participant made their
response, or for a maximum of four seconds. Following the response, a blank screen appeared for 850 ms until the next trial.

Data Analyses

Mean RTs and accuracy calculated. First, RTs were filtered to include only correct responses made within 200 and 1200 ms and were additionally cleaned to remove responses 2.5 standard deviations above and below the participant’s mean. Overall mean RTs and accuracy were calculated based on these remaining data points.

3.2.8 AX-CPT

Recently, it has been suggested that the observed bilingual cognitive advantages are best explained by the fact that bilinguals exploit a combination of executive control processes (e.g., Bialystok, Craik, & Luck, 2012). In addition, it has been claimed that the combination of control processes underlying most types of cognitive performance can be understood as a mixture of proactive control and reactive control (e.g., Braver, 2012). Thus, the AX-CPT task is well-suited to examine whether the interplay between executive control processes underlies differences between L2 learners’ and monolinguals’ executive control since it jointly tests proactive and reactive control.

Procedure

This task was adapted from the AX condition of the Continuous Performance task used by Morales, Gómez-Ariza and Bajo (2013). Participants were instructed that they were to respond to a sequence of five consecutively presented letters. The first letter was a cue, which they had to hold in memory and informed them on how they should respond to the last letter. The last letter was a probe. The target of the sequence was the letter X appearing in the final position as the probe. They were told that they would respond to the letter X by pressing yes only if the letter A appeared
as the cue (in the first position of the sequence). If any other letter appeared as the cue they pressed *no* to the X. No matter what letter appeared, the first four letters of the sequences always required a *no* response be made. Cue letters could be the letter A or any letter that could not easily be confused with X because of its shape. Probes could be the letter X or any other letter besides A, K, or Y. The remaining positions could contain any letter besides, A, K, X, or Y. These combinations of probes and cues led to four conditions. In AX conditions the A cue and X probe were presented together. In BX conditions, any letter besides A preceded the X probe. In BY conditions, all combinations of cue and probe aside from the A-X combination appeared. Finally, in AY conditions, the A cue preceded any probe but X.

Participants completed ten trials in which the program presented their cumulative accuracy as feedback. Then they completed one block of 100 experimental trials. During both practice and experimental blocks, 70% of trials appeared from the AX condition. The remaining trials were divided evenly among the BX, BY, and AY conditions.

Participants pressed the yes button to initiate a trial. Each letter appeared at the center of the screen for 300 ms, followed by a 1000 ms blank screen. A 1000 ms interval separated trials.

*Data Analyses*

Mean RTs and accuracy calculated. First RTs were filtered to include only correct responses made within 100 and 1000 ms (according to the procedure of Morales, Gómez-Ariza, & Bajo, 2013) and then were additionally cleaned to remove responses 2.5 standard deviations above and below the participant’s mean. Overall mean RTs and accuracy were calculated based on these remaining data points. Mean RTs and accuracy were calculated for the AX, AY BX, and BY conditions. Finally the difference between performance on AY and BY (AY minus BY) was used to quantify the degree of reliance on reactive and proactive control strategies.
3.2.9 English Verbal Fluency

English proficiency was also assessed using the verbal fluency task. Previous research suggests, that like lexical decision tasks, verbal fluency indexes global language proficiency (e.g., Linck, Schweiter, & Sunderman, 2011). Highly proficient bilinguals and monolinguals also demonstrate large differences on verbal fluency performance and this is hypothesized to reflect a general weakness in lexical access that characterizes bilingualism (e.g., Gollan & Montoya, 2005). For L2 learners, the task may measure the degree of sensitivity they have to the L2 or their increasing bilingualism (e.g., Linck et al., 2009).

Materials

Four animate categories were adapted from (Linck et al., 2009). Participants named exemplars from the animal, body parts, fruits, and vegetable categories.

Procedure

Participants were seated in front of a computer with an S-R box, microphone, and a digital recording device. They were asked to put on a pair of headphones and to read the instructions. The instructions appeared on the screen and explained that they would see a category word (e.g. “FRUITS”) appear at the center of the screen. They were told that the word would disappear and they would hear a tone through the headphones. Once they heard the tone, they had 60 seconds to generate as many examples from the category as possible. After 60 seconds, the word “STOP” appeared on the screen and they heard another tone. This signaled the end of a trial. They pressed the third button on the S-R box to begin the next trial.

Data Analyses

Recorded responses were transcribed and scored based on the following criteria developed by Linck (2005): (1) the response was scored as correct if it was an example of the presented
category; (2) the response was scored as a repetition if the same example had already been given; (3) the response was scored as a superordinate category if it was a general example (e.g., shoes), followed by specific types of the general example (e.g., running shoes, walking shoes); (4) the response was scored as an error if the example did not belong to the given category. The total number of correct and superordinate category responses was counted for L1 and for L2 separately and divided by the number of categories that they performed.

3.2.10 Spanish verbal fluency

Spanish verbal fluency was used to collect information about participants’ Spanish vocabulary knowledge. As with the English verbal fluency, I expected that it would also provide information about participant’s growing sensitivity to the L2.

Materials

The same categories were used in English and Spanish verbal fluency. The English round of verbal fluency always preceded the Spanish verbal fluency. This was done to eliminate the possibility of after-effects of speaking Spanish on English verbal fluency performance.

Procedure

The procedure was identical to the English verbal fluency task.

Data Analyses

The scoring and analytical treatment of the Spanish verbal fluency data was identical to that of the English verbal fluency, except a fluent or near-fluent Spanish speaker transcribed the data. In addition to marking repetition errors, errors reflecting language intrusions (e.g., dog for perro) or incomplete knowledge about the lexical form of the Spanish word were marked. Lexical form errors were responses that resembled real Spanish words, but had 2 or more incorrect phonemic segments (e.g., zanera-nonword for zanorhia-carrot).
Chapter 4: Experiments 1 and 2- Using the native language to evaluate the consequences of learning to speak a second language

In the following section, I present a manuscript to be submitted for publication containing the results and discussion of Experiments 1 and 2. These experiments examined the scope and time course of language regulation for L2 learners using a novel approach that focused on the consequences of attempting to speak the L2 on L1 production. Brief discussion of each of the major questions raised in the larger body of the thesis is included within the manuscript itself. Namely, does the blocked picture naming paradigm provide a suitable methodology for examining L2 speech planning processes for learners? To what extent do the patterns of regulation observed when L2 learners plan speech suggest the presence of inhibition? Is there evidence for extended consequences of speaking the L2 for learners that manifest even when the speech is performed in the L1 alone? For a more comprehensive summary, the general discussion of the thesis responds to the broader issues that were outlined in the introduction.
Using the native language to evaluate the consequences of learning to speak a second language

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Abstract

When proficient bilinguals prepare to speak the second language (L2), there is evidence for inhibition of the more dominant language (L1). The question we ask in the present study is how these demands are manifest for L2 learners who are arguably in a much more challenged position than proficient bilinguals with respect to controlling a highly dominant L1 when they have to speak a barely proficient L2 (e.g., Costa & Santesteban, 2004). We examined L1 production in three groups of native-English speakers. Two groups were learning Spanish as an L2 and the third was monolingual. All groups named eight blocks of pictures. The first block was always in English. One group of learners then named a second block in Spanish. The other learners and monolinguals named this second block in English. Pictures in Blocks 3-8 were named in English but included new items and repetitions from first two blocks. Behavioral measures showed an inhibitory consequence for learners when the L1 followed production of the L2 that included reduction in repetition priming, but the ERP record did not reveal an inhibitory effect. Learners who spoke only the L1 experienced priming, similar to monolingual controls. The evidence suggests that there are immediate consequences of speaking the L2 on subsequent L1 production for learners, but no extended consequences when speech is planned in the L1 alone. Taken together, these results suggest that inhibition should figure less prominently in models of L2 speech planning than models of proficient bilingual speech planning.
Using the native language to evaluate the consequences of learning to speak a second language

**Introduction**

Adult second language (L2) learners are notorious for being able to comprehend (e.g., Midgley, Holcomb, & Grainger, 2009; Sunderman & Kroll, 2006), but not speak the L2 (e.g., Tokowicz, Michael, & Kroll, 2004). Producing single words in the L2 is a difficult task for learners at early stages (e.g., Kroll, Michael, Tokowicz, & Dufour, 2002). Unskilled production makes experimental studies of learners’ speech planning difficult because learners frequently fail to speak. L2 learners might not have adequate lexical knowledge or be able to access the phonology for the words that they do know (e.g., Sunderman & Kroll, 2009). Gaps in L2 vocabulary create a large number of missing data points, making it virtually impossible to use the experimental methods that have been adopted to investigate proficient bilingual speech. Indeed, it is impressive given the asymmetry in language dominance that learners manage to speak the L2 at all.

In the present study we take a new approach to lexical production in L2 in learners by focusing not on the L2 directly, but on the indirect effects of attempting to plan speech in the L2 on the L1. A recent body of research on relatively proficient bilinguals (Guo et al., 2011; Misra, et al., 2012; Van Assche et al. 2013) has shown that production of the native language (L1) changes when bilinguals have just spoken the L2. Those changes have been documented in studies of language switching (e.g., Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Finkbeiner, Gollan, & Caramazza, 2006; Hernandez, Martinez, & Kohnert, 2000; Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001; Linck, Schweiter, & Sunderman, 2012;
Meuter & Allport, 1999; Verhoef, Roelofs, & Chwilla, 2009) and in studies of blocked production where switches occur not from trial to trial, but after blocks of naming in one language alone (e.g., Branzi, Martin, Abutalebi, & Costa, 2014; Misra et al., 2012; Phillip, Gade, & Koch, 2007; Phillip & Koch, 2009). The hypothesis in this recent work is that even highly proficient bilinguals must regulate the activation of the L1 to enable L2 production. In what follows, we first consider the evidence for highly proficient L2 speakers and then turn to predictions for L2 learners. At a general level, we expect that L2 learners will require greater control of the L1 to speak the L2 than proficient bilinguals whose languages are more closely balanced (e.g., Costa & Santesteban, 2004).

The inhibitory hypothesis of bilingual language control

Studies of proficient bilingual speech production show that both languages are activated even when one language alone is spoken (e.g., Costa, 2005; Costa, Miozzo, & Caramazza, 1999; Costa, Caramazza & Sebastián-Gallés, 2000; Hermans, Ormel, van Besselar & van Hell, 1998; Hoshino & Kroll, 2008; Hoshino & Thierry, 2011; Pyers & Emmorey, 2009). The consequences of parallel activation of the two languages should be even more pronounced for L2 learners than for proficient bilinguals. For L2 learners, the L1 is so much more dominant and skilled than the emerging L2 that there may need to be constant regulation to prevent the use of L1 when attempting to speak L2. Models of bilingual speech planning have considered the way that this regulatory process might operate in proficient speakers to enable fluent L2 speech. We consider here how models of proficient bilingual speech planning might be adapted to characterize these processes in learners.

The Inhibitory Control model (Green, 1998) assumes that the L1 requires control so as not to interfere with L2 production. According to the model, in order to produce speech,
bilinguals must select among L1 and L2 language task schemas. The Inhibitory Control model predicts that because the L1 is typically more dominant than the L2, even for highly proficient bilinguals, the task schema for producing L1 is more strongly activated. As a consequence, the intention to speak the L2 is not sufficient on its own to bias activation of words to the L2 exclusively. Competition between words in the L1 and L2 is assumed to be particularly prevalent when bilinguals attempt to speak in the weaker L2. In order to overcome the competition between words during L2 speech planning, the model assumes that bilinguals inhibit the L1. By comparison, the L2 is much less likely to interfere with the more dominant L1. Therefore, the model predicts that inhibition is engaged most strongly when attempting to speak the L2. Critically, inhibition is proportional to the amount of conflict induced by the respective language, meaning that the bilingual’s relative proficiency in L1 and L2 affects the level of control directed at each language. For L2 learners, a large asymmetry between the strength of the L1 and L2 implies that they engage a great deal of L1 inhibition whenever they attempt to speak L2.

**Asymmetries in language switching**

Early behavioral studies of language switching appeared to provide support for the hypothesis that proficient bilinguals produce speech in their L2 by inhibiting the L1. In a standard switching paradigm, bilinguals are asked to name digits or pictures according to a cue, providing a means for inferring the extent to which control processes must be engaged for speaking the L1 and the L2. Meuter and Allport (1999) conducted a language switching study in which bilinguals named digits either in their L1 or in their L2 based on the background color of the digit. Switch trials included trials in which the language of production differed across adjacent trials whereas non-switch trials included adjacent trials in which the language of production remained the same. The switch cost, the cost of speaking on a switch trial relative to
speaking on a non-switch trial, was used as an index of inhibition. Meuter and Allport found that late bilinguals dominant in their L1, showed asymmetric switch costs. If planning speech in the L2 requires inhibition of the L1, then on the next trial when the L1 must be produced, that inhibition must be overcome. Because the production of L1 does not require inhibition of the less dominant L2, the switch costs will be asymmetric, depending on the direction of the switch. Subsequent studies have replicated the switch cost asymmetry, suggesting that inhibition of the L1 characterizes one aspect of bilingual language control (e.g., Jackson, Swainson, Cunnington, & Jackson, 2001; Philipp, Gade, & Koch, 2007; Schwieter & Sunderman, 2008; Verhoef et al., 2009).

Because some highly proficient bilinguals are more balanced in the two languages, without one language dramatically more dominant than the other, Costa and Santesteban (2004) questioned whether all bilinguals show evidence of the same switch cost asymmetry. To investigate this issue they conducted a language switching study that directly compared the performance of less and more proficient bilinguals. Less proficient bilinguals who were unbalanced in language dominance replicated the pattern of switch costs asymmetries that had been reported in the previous studies. However, the highly proficient bilinguals who were balanced in their language dominance revealed symmetric switch costs. The differences between the pattern of switch costs for less and more proficient bilinguals suggested that there was a developmental trajectory from an early stage in which the L1 is actively inhibited to a later stage in which this sort of active inhibition is not required. Costa and Santesteban (2004) hypothesized that highly proficient bilinguals are able to select the language they intend to speak early in speech planning without engaging inhibition.
Multiple components of language selection

Costa and Santesteban’s (2004) study suggests that there are two mechanisms of language selection that depend on proficiency. But proficiency may not be the only factor that determines the mechanism of language selection. The locus of language selection, referring to the point during speech planning at which the intended language of production controls speech planning processes, is also debated. There is increasing evidence that the locus of language selection depends on many factors, including proficiency, whether production is planned in the L1 or the L2, the task that initiates speech planning, and the relationship between the bilingual’s two languages (for a review, see Kroll, Bobb, & Wodniecka, 2006). The asymmetries found in the initial studies of language switching were interpreted as evidence that, in the presence of a stronger L1, the L1 must be suppressed to enable L2 to be produced (e.g., Jackson et al., Meuter & Allport, 1999; Phillip & Koch, 2007; Schweiter & Sunderman; Verhoef et al., 2009). The data reported by Costa and Santesteban (2004) showed that switch costs can be symmetric or asymmetric depending on the proficiency of the bilinguals tested. But their data also showed that all bilinguals, not only the less proficient or L1 dominant bilinguals, were slower to name pictures in L1 than in L2 under these conditions of mixed language picture naming. The slower naming latencies for the L1 might be taken as global inhibition for all speakers, regardless of L2 proficiency (and see Bobb & Wodniecka, 2013 for an analysis of language switch costs). The observation of language mixing costs and overall slowing of L1 under mixed language picture naming conditions suggests that language switch costs may not provide the only, or even the most accurate index of inhibitory control during speech planning. In recent studies, this issue has been examined by using a blocked picture naming paradigm in which languages are switched, but only after an extended period of naming.
In a recent event-related potential (ERP) study, Misra, Guo, Bobb, and Kroll (2012) examined the time course of language regulation during lexical production using a blocked picture naming paradigm. A group of relatively proficient Chinese-English bilinguals named pictures first in the L1, maintaining the same language over successive trials within blocks, and then switched into the L2 for the remaining blocks. A separate group of Chinese-English bilinguals named pictures first in the L2 and then switched into the L1. Pictures were repeated across the L1 and L2 language blocks. Typically, repetition leads to facilitation and one would expect that bilinguals would benefit from repetition priming in the switched blocks. Instead, if naming pictures initially in one language produces inhibition when the other language must be spoken, then there would be reduced priming or no priming for repetitions. Evaluation of the ERPs, focusing on the early N200, late N200, and the LPC components, demonstrated positivity (priming) when bilinguals named pictures in the L2 after the L1, but negativity (interference) when bilinguals named pictures in the L1 after the L2. The pattern of results suggested there was inhibition of the L1 after speaking the weaker L2. Because the same pictures were repeated, Guo et al. expected strong priming for the repetition of the same perceptual and conceptual information. The increased negativity during the early and late N200 windows for the L1 following the L2 suggested that there was an inhibitory process that counteracted the facilitation attributable to priming. Misra et al.’s study was designed so that bilinguals named two blocks of pictures in one language followed by two blocks of pictures in the other language. It might be expected that in the condition in which the L1 was spoken following the L2 there would be an inhibitory pattern initially, followed by recovery. If so, performance in the second block of L1 naming would resemble naming when the L1 is named prior to L2. The surprising finding in this study was that recovery was not observed. The pattern of inhibition persisted through the second
block of L1 naming, suggesting a mechanism of language control in production that is long-lasting.

Mechanisms of language regulation may also vary in scope. The scope of language regulation could be one of the bilingual’s two languages as a whole or a specific word not to be spoken, or some intermediate alternative (e.g., word in a particular semantic category). Misra et al.’s (2012) study was able to examine the time course of inhibition, but because the same items were named across blocks, the study could not directly test the scope of inhibition. Branzi, Martin, Abutalebi, and Costa (2014) examined the scope of language regulation by adapting the design of Misra et al.’s study to include repetitions and new pictures. If the scope of language control were the whole language, then one would expect that the ability to name new pictures would be affected when bilinguals speak the L1 after the L2. ERPs revealed modulations of the N200 when bilinguals named new pictures as well as repeated pictures, suggesting that the scope of inhibition can generalize to the entire language itself.

Two recent studies, one using behavioral methodology and another neuroimaging methodology, provide further evidence that bilinguals exploit multiple forms of language control for lexical production. Guo, Liu, Misra, and Kroll (2011) examined the neural correlates of bilingual language production using fMRI and found evidence for both lexically-specific and global inhibitory processes. They examined the patterns of neural activity observed when Chinese-English bilinguals switched between L1 and L2 in the context of a mixed language naming task and when they switched between L1 and L2 in a blocked fashion, naming one language at a time. Different brain regions were activated during the two types of switching. Guo et al. identified the consequences of switching between language blocks as reflecting global
inhibitory processes, but the overall difference between blocked and mixed picture naming as reflecting local inhibitory processes.

Van Assche, Duyck, and Gollan (2013) examined verbal fluency performance in two groups of relatively proficient bilinguals. Like the Misra et al. (2012) and Guo et al. (2011) studies, they varied the order of the languages in which bilinguals performed the verbal fluency task. The two groups tested by Van Assche et al. differed in whether they were immersed in the L1 or L2 environment. The critical result was that again there was evidence for multiple components of inhibitory control but in this study, the pattern of inhibitory control depended on the type of bilingual. Dutch-English bilinguals in Belgium and Chinese-English bilinguals in the U.S. both produced lexically-specific inhibition when producing exemplars from verbal fluency categories that were repeated from L2 to L1. However, only Chinese-English bilinguals produced global inhibition for new categories in the verbal fluency task. Taken together, the results of these studies provide evidence for multiple mechanisms of inhibitory control that are modulated by proficiency, the production task, variation in bilingual language context, and additional factors.

The current study

Here we report two experiments. Experiment 1 used the blocked picture naming paradigm to investigate the consequences of speaking the L2 on the L1 for L2 learners. As noted before, there are few, if any, prior studies that have examined the electrophysiological correlates of speech planning in L2 learners. The evidence reviewed above suggests that when highly proficient bilinguals plan speech in the L2 and later speak the L1, there is a cost to the L1. Misra et al. (2012) used ERPs to examine the consequences of speaking the L2 for the L1 and found inhibitory patterns in the neural record that were very long-lasting, suggesting L1 costs. We used
the temporal precision of ERPs to track moment-by-moment changes to L2 learners’ speech planning processes and asked whether the neural correlates observed for learners reveal L1 costs similar to those observed for more proficient bilingual speakers (as in Misra et al., 2012). Specifically, if the neural correlates of the consequences of speaking the L2 on the L1 were similar for L2 learners and more proficient bilinguals, like those from Misra et al.’s study, then we expect learners to show significant modulations of ERP components related to inhibition (i.e., N200). However, if L2 learners do not show consequences of speaking the L2, then the prediction is that the ERPs would reveal sensitivity to lexical and semantic priming manipulations (e.g., N400).

Experiment 1 also investigated the neural signature associated with L2 learners’ lexical production in the L2. Previous studies have avoided investigating L2 speech in L2 learners because learners produce few words in the L2, leaving the developmental trajectory of bilingual speech planning processes unresolved. Although the main focus of the study was on L1 production before and after speaking the L2, it was also possible to use the data from the very first blocks of L1 and L2 naming to compare naming in the two languages directly (e.g., Strijkers et al., 2009). We predicted that since there are many aspects of speech planning impacted by learners’ weak L2 proficiency (e.g., conceptual processing, phonological processing, articulation), there should be extensive differences found in the ERPs when L2 learners speak the L1 and the L2. Furthermore, recent studies that have focused on proficient bilinguals demonstrate that both early stages of lexical access (e.g., Runnqvist, Strijkers, Sadat, & Costa 2011) and late stages of articulation (e.g., Parker-Jones et al., 2012) are influenced by bilingualism (e.g., Hanulovà, Davidson & Indefrey, 2011). Therefore, we speculated that
multiple ERP components, encompassing early (e.g., P200) and later (N300, N400) time windows might differ for L1 and L2 speech planning.

Blocked picture naming studies have revealed long-lasting costs to the L1 that resemble the phenomenology that individuals report during or after language immersion experience. Following L2 immersion, speakers often report an inability to speak the L1 fluently (e.g., Baus et al., 2013; Linck, Sunderman, & Kroll, 2009). Critically, evidence on lexical production in immersed L2 learners suggests that increases in L2 production causes instability to L1 speech planning. We speculate that instability occurs because extensive L1 regulation must take place in order for learners to speak the L2. What is not clear is precisely how extensive processes of L1 regulation are. For example, these mechanisms may be very long-lasting in time course. If so, one consequence of bilingualism is that the L1 may be affected by processes of L1 regulation all the time. In Experiment 2, we examined lexical production when L2 learners and monolinguals completed a blocked picture naming task in the L1 alone.

**Experiment 1: Examining the scope and the time course of the consequences of speaking the L1 after the L2**

In Experiment 1, we modified the blocked picture naming paradigm to examine the time course of the consequences of speaking the L1 after the L2. Misra et al. (2012) reported inhibitory effects in production that extended longer than anticipated. They included two blocks of L1 production, one immediately following L2 production and the other after the L1 had been spoken for a full block of naming. Counter to expectations, they found little evidence for recovery from inhibition even when there had been an opportunity to speak the L1 for a period of time. In the current study we asked whether recovery from the consequences of naming in the L2 would be observed in a paradigm in which there were additional blocks of naming in the L1.
That is, Misra et al. (2012) may not have waited long enough for recovery to be observed. In the current study, participants first named a block of pictures in L1 and then named a second block of pictures in L2. The six subsequent blocks of picture naming required L1 naming only. The design of the experiment can be conceptualized as a study-test paradigm. Blocks 1 and Blocks 2 served as the study conditions during which an initial set of pictures were first presented and named in L1 and L2, respectively. Different pictures appeared in each of the first two blocks. To the extent that there are consequences for the L1 when learners plan speech in the L2, the six test blocks were named only in the L1. Irrespective of whether the consequences of speaking the L2 on L1 speech are indeed inhibitory, we predict that the large difference in skill associated speaking the L1 and L2 would produce extended consequences for L2 learners.

In addition to providing an index of the time course of L1 naming following L2, the last six blocks of the study were designed to assess the scope of the consequences of speaking the L2 on L1. The final six blocks included pictures that had been named previously in either the L1 or the L2 during Blocks 1 and 2, respectively. In each of the six blocks, there were repeated pictures that had been named in L1 in Block 1 or in L2 in Block 2. There were other pictures that were new but sampled from categories that had been presented in the study blocks. A third set of pictures in each block was new, with pictures that had not been named or seen previously in the experiment. The repetition manipulation included in the later blocks enabled us to generate a rich set of predictions regarding the scope of the consequences of speaking the L1 after the L2. One prediction is that speaking the L2 globally affects the ability to speak the L1. If speaking the L2 globally affects the L1, learners should experience costs naming completely new pictures during the later L1 blocks. New pictures presented during the later L1 blocks should produce longer naming latencies than those during Block 1, when pictures were first named in the L1. Another
prediction is that speaking the L2 influences the ability to speak words that overlap with a previously named semantic category. If so, there should be differences observed when learners name new pictures from previously named semantic categories relative to when they name completely new pictures. The repetition of semantic category information might facilitate picture naming if it acts as a form of priming (e.g., Dell’Acqua & Grainger, 1999; Lupker, 1988). However, it is possible that speaking the L2 may reduce or eliminate the priming from repeated category information when the pictures at test need to be named in L1.

An alternative is that the consequence of speaking the L1 following the L2 is more local, affecting the ability to produce specific words in L1 that were previously named in L2. Generally, repeating pictures facilitates subsequent naming (e.g., Barry, Hirsh, Johnston, & Williams, 2001; Cave, 1997; Cave & Squire, 1992; Mitchell & Brown, 1988). However, speaking the L2 may reduce or eliminate the lexically-specific repetition benefit. The presence of local effects of L2 on L1 at the lexical level is not necessarily incompatible with global effects at the semantic level or the level of the entire language. It is possible that each of these factors contributes to the observed production of L1 during the test phase of the experiment. Likewise, it is possible that the time course of these effects differ. Some effects may be long-lasting and others short-lived. The design of the test phase of the current experiment will enable us to ask about each of these questions and to determine whether the consequences of speaking L2 on the L1 are extended in time.

**Method**

**Participants**

Eighteen students of Penn State University participated in the experiment. All participants were right-handed, had normal or corrected-to-normal vision, and no history of
neurological disorder. Participants were native English speakers with intermediate-level proficiency in Spanish. They were all late learners who had studied Spanish since age 12 on average and had a minimum of two college semesters of Spanish instruction (mean: 5.11 semesters). They were dominant in their L1 (English) in reading, writing, speaking, spelling, and listening skills as self-reported on a language history questionnaire. Table 1 summarizes the language ratings of the participants who were tested in Experiments 1 and 2.

Table 1
Self-ratings of proficiency

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 2</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>L2 learners:</td>
<td>L2 learners:</td>
<td>Monolinguals:</td>
</tr>
<tr>
<td></td>
<td>L1 after L2</td>
<td>L1 alone</td>
<td>L1 alone</td>
</tr>
<tr>
<td>English (L1)</td>
<td>9.89 (.32)</td>
<td>9.89 (.32)</td>
<td>9.67 (.77)</td>
</tr>
<tr>
<td>Spanish (L2)</td>
<td>7.56 (1.34)</td>
<td>6.94 (1.35)</td>
<td>3.22 (1.63)</td>
</tr>
<tr>
<td>Reading</td>
<td>9.67 (.59)</td>
<td>9.83 (.38)</td>
<td>9.39 (.70)</td>
</tr>
<tr>
<td>Writing</td>
<td>7.06 (1.51)</td>
<td>6.39 (1.42)</td>
<td>2.22 (1.11)</td>
</tr>
<tr>
<td>Speaking</td>
<td>9.83 (.38)</td>
<td>9.94 (.24)</td>
<td>9.83 (.38)</td>
</tr>
<tr>
<td>Spelling</td>
<td>7.94 (1.71)</td>
<td>7.39 (1.85)</td>
<td>3.94 (2.07)</td>
</tr>
<tr>
<td>Listening</td>
<td>9.94 (.23)</td>
<td>9.94 (.24)</td>
<td>9.89 (.47)</td>
</tr>
<tr>
<td></td>
<td>7.61 (1.50)</td>
<td>7.01 (1.70)</td>
<td>2.24 (1.03)</td>
</tr>
</tbody>
</table>

Note: Self-ratings of proficiency are based on a scale of 1–10, where 10 indicates the highest level of fluency. Means and standard deviations (in parentheses) are reported.

Since learners were still acquiring the L2, but rated themselves high in L2 proficiency, English and Spanish lexical decision (LDT) tasks were used to provide objective information about learners’ L1 and L2 proficiency. In addition, working memory and executive control were assessed using the Operation Span task (Turner & Engle, 1989) and the Flanker task (e.g., Luk, Anderson, Craik, Crady, & Bialystok, 2010), respectively. Table 2 summarizes the cognitive and language profile of the participants who completed Experiments 1 and 2.
### Table 2
Language and cognitive profile

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th></th>
<th>Experiment 2</th>
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<th>Experiment 2</th>
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<tbody>
<tr>
<td></td>
<td>L2 Learners</td>
<td>L2 Learners</td>
<td>Monolinguals</td>
<td></td>
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<tr>
<td></td>
<td>L1 after L2</td>
<td>L1 alone</td>
<td>L1 alone</td>
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<tr>
<td><strong>RT</strong></td>
<td></td>
<td>Accuracy</td>
<td><strong>RT</strong></td>
<td>Accuracy</td>
<td><strong>RT</strong></td>
<td>Accuracy</td>
</tr>
<tr>
<td><strong>English LDT</strong></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>recognized word</td>
<td>640 (70)</td>
<td>96 (3)</td>
<td>611 (124)</td>
<td>93 (4)</td>
<td>609 (72)</td>
<td>90 (3)</td>
</tr>
<tr>
<td>rejected nonword</td>
<td>756 (203)</td>
<td>93 (8)</td>
<td>680 (140)</td>
<td>91 (4)</td>
<td>683 (100)</td>
<td>89 (3)</td>
</tr>
<tr>
<td><strong>Spanish LDT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>recognized word</td>
<td>902 (227)</td>
<td>80 (7)</td>
<td>909 (275)</td>
<td>74 (10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rejected nonword</td>
<td>1056 (357)</td>
<td>84 (8)</td>
<td>1026 (332)</td>
<td>85 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operation Span</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>correct recalled</td>
<td>2330 (527)</td>
<td>88 (9)</td>
<td>2048 (334)</td>
<td>90 (8)</td>
<td>2119 (288)</td>
<td>91 (6)</td>
</tr>
<tr>
<td><strong>Flanker Effect</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>difference score</td>
<td>43 (23)</td>
<td>*</td>
<td>43 (27)</td>
<td>*</td>
<td>44 (35)</td>
<td>*</td>
</tr>
<tr>
<td><strong>Flanker Congruent</strong></td>
<td>465 (66)</td>
<td>98 (3)</td>
<td>449 (43)</td>
<td>99 (1)</td>
<td>386 (82)</td>
<td>98 (4)</td>
</tr>
<tr>
<td><strong>Flanker Control</strong></td>
<td>362 (37)</td>
<td>97 (4)</td>
<td>364 (40)</td>
<td>99 (2)</td>
<td>450 (76)</td>
<td>99 (2)</td>
</tr>
</tbody>
</table>

Note: LDT mean reaction times are indicated in milliseconds. Flanker effect was also calculated in milliseconds. Accuracies are reported in percentage. *Accuracy is not reported for the Flanker Effect. Standard deviations are indicated within parenthesis.

**Materials**

One hundred and ninety-two pictures were selected from nine semantic categories: Animals, Body Parts, Clothing, Foods, Furniture, Kitchen Items, Tools, Vegetables, and Vehicles. Each picture was displayed in line drawing, color photograph or black and white photograph format in order to reduce the priming associated with presenting an identical picture. The colored and black and white photograph images were retrieved from Google Images. Line drawings were taken from the Snodgrass and Vanderwart (Snodgrass & Vanderwart, 1980) picture database and Google Images. Pictures were controlled for their dimensions, and were 400 x 400 pixels. A set of 486 picture stimuli was created.
There were a total of eight blocks presented during the task. Pictures were assigned to conditions that targeted the lexically-specific, category-specific, and global levels of language control. Pictures were matched as closely as possible across conditions for the number of syllables in the picture’s name, frequency, familiarity, and number of taxonomic features, which are variables that have been found to influence picture naming latencies in past research (e.g., Alario et al., 2004; Cuetos, Ellis, & Alvarez, 1999; Snodgrass & Yuditsky, 1996). The characteristics of the pictures are summarized in Table 3.

### Table 3
Characteristics of Pictures and Picture Names

<table>
<thead>
<tr>
<th>Variable</th>
<th>Blocks 1 and 2</th>
<th>New Items</th>
<th>New Items</th>
<th>New Items</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>from Block 1 Categories</td>
<td>from Block 2 Categories</td>
<td>from New Categories</td>
<td>(F-test)</td>
</tr>
<tr>
<td>Number of Syllables</td>
<td>1.4 (.55)</td>
<td>1.5 (.74)</td>
<td>1.5 (.94)</td>
<td>1.7 (.70)</td>
<td>ns</td>
</tr>
<tr>
<td>Frequency</td>
<td>21.2 (33.5)</td>
<td>22.4 (35.2)</td>
<td>28.0 (28.6)</td>
<td>21.3 (26.4)</td>
<td>ns</td>
</tr>
<tr>
<td>Familiarity</td>
<td>6.9 (2.0)</td>
<td>6.6 (1.4)</td>
<td>7.3 (1.3)</td>
<td>6.7 (1.5)</td>
<td>ns</td>
</tr>
<tr>
<td>Number of features</td>
<td>14.8 (4.2)</td>
<td>15 (3.3)</td>
<td>14.7 (2.8)</td>
<td>14.7 (3.0)</td>
<td>ns</td>
</tr>
</tbody>
</table>

**Notes.** Blocks 1 and 2 were the same items but counterbalanced across participants, therefore means are averaged together. a Kučera & Francis (1967); Per million words. b Data from the MRC Psycholinguistic database (Coltheart, 1981). c Data from the English Lexicon Project database (Balota et al., 2002). d McRae et al. (2005); Number of taxonomic semantic features.

Twenty-seven pictures were selected for presentation during Block 1. Then, 27 additional pictures were selected for presentation during Block 2. Pictures that first appeared during Block 1 or Block 2 were named again during Blocks 3-8 as lexically-identical repetitions from Block 1 and lexically-identical repetitions from Block 2. In addition to lexically-identical repetitions from Blocks 1 and Block 2, two types of new pictures were presented during the later blocks (Blocks 3-8). New pictures drawn from categories that were initially presented during Block 1 (new from Block 1) or Block 2 (new from Block 2). For example, if Block 1 included items from the category animals, an animal which was not presented in Block 1 might then be included as a new
picture from Block 1 categories. In addition to new pictures from previously named categories, a set of entirely new pictures drawn from categories not previously seen were included in the later blocks of the experiment (new). To ensure that lists were matched properly, all pictures were assigned to condition lists using a matching algorithm (Match.exe, Van Casteren & Davis, 2007).

In addition, pictures were assigned to lists according to when they appeared during the eight blocks of the experiment. The study and test blocks were counterbalanced across participants to ensure that items were named in different orders. To adequately match the lexical properties of the pictures that appeared in the six later test blocks, these later blocks were divided into three test blocks (e.g., Blocks 3 and 4, Blocks 5 and 6, and Blocks 7 and 8). Satisfying the matching requirement compromised some of the precision in tracing the time course of the effects throughout the task. However, since three pairs of test blocks were retained after the matching procedure we expected that it would still be possible to detect graded changes to the L1 during the later test blocks. Critically, during the later test blocks pictures were cycled so that a picture only appeared within one of the three later test blocks. For example, if “shoe” was an item assigned to Blocks 3 and 4 as a lexically-identical repetition, the picture was named first in Block 1, then named during Blocks 3 and 4, but then could not be presented as a stimulus later in the experiment.

**Procedure**

Participants were tested individually in a sound-proof testing room. They were seated in a comfortable chair approximately 20 inches away from a Dell computer monitor. A microphone attached to the S-R box was placed directly in front of the participant as closely as possible without occluding their vision. In the blocked picture naming task, participants first received instruction in English on the computer screen. They were informed that a series of pictures
would appear on screen and that they would name pictures during some sections in the L1 and some sections in the L2. At the beginning of each trial, a fixation sign (+) was presented at the center of the computer screen for 500 ms. After the offset of the fixation sign, a picture was presented. The picture was presented for 1000 ms or until the participants responded. After they responded, a blank screen was presented for 1000 ms and a fixation sign appeared again. If participants did not know the name of the picture, they were instructed to be silent. Participants received 10 practice trials of English picture naming before Block 1 and 10 practice trials of Spanish naming before Block 2. To avoid introducing potential strategies, there was no familiarization with picture names prior to testing. The pictures used during practice and experimental trials were different items.

**Behavioral Data Analysis**

Recorded picture naming responses were first transcribed and scored for accuracy. Responses that included the expected name of the picture and responses that included synonyms or close semantic relatives were counted as correct. Responses that were unrelated to the expected picture name, responses that started with an article or hesitation, and omissions were scored as errors. Responses that the microphone did not detect were eliminated as technical errors. After trimming response latencies for correct responses that were less than 300 ms or greater than 3000 ms for both L1 and L2 trials, response latencies that were 2.5 standard deviations above or below the mean were identified as outliers and excluded from the analyses. Finally, accuracy and response latencies for correct responses were calculated. Errors (8.4 %), outliers (4.4 %), and technical errors (0.91 %) were excluded from the analyses. Because participants were not pre-trained on the picture names, relatively liberal criteria were used to judge whether a picture was named correctly. Items for which participants responded with an
answer that was somewhat imprecise but correct (e.g., “drawers” for “dresser”) and pronunciation errors in L2 were marked as correct answers.

A series of repeated measures ANOVAs evaluated how the requirement to speak the L2 impacted performance in the blocked naming conditions for both response latencies and accuracy. Two sets of analyses were performed. In the first one, L1 and L2 naming (i.e., the first time the picture was presented in each language) during Blocks 1 and 2 were compared. These analyses allowed us to examine the predicted differences in processes that underlie L1 and L2 speech planning. In the second set of analyses, initial L1 naming during study and subsequent L1 naming during the test blocks were compared to determine whether there were consequences of L1 regulation that persisted beyond the immediate context of speaking the L2. Regulation over time was examined by comparing naming in the first L1 block to naming of new items in subsequent L1 later test blocks (Blocks 3 and 4, Blocks 5 and 6, Blocks 7 and 8). Recall that for the sake of assessing the scope of language regulation, lexically-identical repetitions of pictures, new pictures from repeated categories and completely new pictures were presented in the subsequent L1 blocks as well.

**ERP Recording and Data Analysis.**

The continuous electroencephalogram (EEG) was recorded using a 32-channel sintered Ag/AgCl electrode array mounted in an elastic cap according to the 10-20 system (QuikCap, Neuroscan Inc.). Recordings were referenced to the left mastoid during recording and re-referenced off-line to the average activity of the left and right mastoids. Electrode impedances were kept below 5 kΩ. Lateral eye movements were measured by electrodes placed on the outer canthus of each eye. Vertical eye movements were measured by electrodes placed on the upper and lower orbital ridge of the left eye. Eye recordings were later used off-line to reject
contaminated trials. The electrophysiological signals were amplified using Neuroscan Synamps with a band pass filter of 0.05 to 100 Hz and a sampling rate of 500 Hz. Only trials with correct responses were included in the analyses. A pre-stimulus baseline of 150 ms and an epoch duration of 600 ms post-stimulus were used to compute average ERPs per condition. Trials with eye movement artifacts or blinks and peak-to-peak deflections over 100 µV were rejected. A digital low-pass filter of 30 Hz (24 dB/oct) was applied when analyzing the data off-line.

Based on visual inspection of the waveform and the previous literature (Misra et al., 2012; Strijkers et al., 2010; Christoffels et al., 2007) two time windows were selected for further investigation. Mean amplitudes were calculated over each of the time windows corresponding to the component of interest, an early negativity, or N200, between 200 and 270 ms, and the N400, between 300 and 450 ms.

Using the criteria described, only correct, artifact-free trials were included in the ERP analyses. To allow for adequate signal-to-noise ratio, the minimum number of trials for computing average ERPs for each condition in each participant was 15. For the participants included in the final sample, 15.17% of trials were rejected after excluding trials with errors and artifacts (8 %, 44%, 11%, 10%, and 12 % for Block 1, Block 2, Blocks 3 and 4, Block 5 and 6, and Block 7 and 8 respectively and 6%, 10%, 13%, 9%, and 13 % for new, new from Block 1, new from Block 2, repeated from Block 1, and repeated from Block 2 respectively). For each component, mean amplitudes over set time windows were computed as dependent variables. For the first set of analyses, for each dependent component, repeated measures ANOVAs comparing language (L1 or L2) were computed over separate electrode groupings. Based on the topographical distribution of the effects we were interested in, separate analyses were completed for the midline and lateral sites. For the midline sites, four levels of electrode site (FZ, CZ, PZ,
and OZ) were included as a second variable. For the medial-lateral sites, variables of hemisphere (2: left/right) and electrode site (5 levels: FP1/FP2, F3/F4, C3/C4, P3/P4, O1/O2) were factored into the ANOVA. For the lateral-lateral sites, variables of hemisphere (2: left/right) and electrode site (3 levels: F7/F8, T7/T8, P7/P8) were factored into the ANOVA. The Greenhouse–Geisser correction was applied to account for non-sphericity of the data (Greenhouse & Geisser, 1959); uncorrected degrees of freedom and corrected probabilities are reported. Only results including the factors of language, block, category repetition, or lexical repetition as main effects or interactions between these factors and electrode site and/or hemisphere are reported, since general topographic differences in electrode site and/or hemisphere per se are to be expected and are not of primary interest in this study.

ERPs were used to determine whether or not there were consequences of speaking the L2 for the L1 that could be observed in the earliest moments of speech planning itself. We also speculated that because previous studies of bilingual speech planning found patterns suggesting costs as well as facilitation for the L1, the temporal precision provided by ERPs might be especially useful for distinguishing the unique contributions of these factors.

Results

Behavioral Analysis

Comparing L1 and L2 in the two study blocks: Block 1 vs. Block 2

ANOVA's were performed on response latencies and accuracy to examine differences in L1 and L2 picture naming during Blocks 1 and 2. Since learners are still in the process of acquiring the L2, we predicted that they would be slower and less accurate to name pictures in the L2 than in the L1. In the analysis of response latencies, the main effect of language was significant \([F(1, 17) = 55.56, \eta_p^2 = .77, p < .001; F(1, 53) = 73.33, \eta_p^2 = .60, p < .001]\). In the
accuracy analysis, the main effect of language was also significant \( F(1, 17)=106.01, \eta_p^2=.86, p<.001; F(1,53)= 96.78, \eta_p^2=.65, p<.001 \].

Figures 1. (A) Mean response latency during Study (Blocks 1 and 2). (B) Mean accuracy during Study (Blocks 1 and 2). Note that Block 2 was performed in the L2 (Spanish).

As predicted, L2 learners were significantly slower and less accurate when they named pictures in the L2 (mean accuracy = 55%) relative to the L1 (mean accuracy = 92%). The majority of the learners’ errors were omissions, raising the question of whether or not the high omission rate would lead to insufficient L2 activation. If later effects of speaking the L2 on the L1 depend on successful naming in the L2, then learners might be expected to reveal reduced consequences for the L1 relative to more proficient bilinguals. However, if the consequences for the L1 are driven by regulation of the L1 itself, then even in the absence of overt L2 naming, there may be a high level of activation of the L1. As a result, subsequent control of the L1 would occur so that the intention to name a picture in Spanish prevents potential intrusions from English (e.g., Green, 1998; Strijkers, Holcomb & Costa, 2012).

**Examining the scope and time course of the consequences of speaking the L2**

In the two set of analyses that follow, we examined the time course of the consequences of speaking the L2 on the L1. The general logic of the analyses was to compare the L1 when it
was produced before and after speaking the L2. For the first analysis, we compared naming that occurred during Block 1 to the naming of new pictures during the later blocks. Like the recent blocked production studies (e.g., Van Assche et al., 2013), we used new items to determine whether or not there were global consequences of speaking the L2 for later production in the L1. In the current study, we also focused on the consequences for naming new pictures since this approach would provide a pure measurement of the consequences of speaking the L1 after the L2. If the regulation of the L1 during L2 picture naming produces global inhibition of the L1, then new items that have not been seen earlier at study and which are not related in any way to previously presented pictures would be predicted to be named more slowly than pictures named in L1 prior to L2 naming. Two additional conditions were included at test to investigate the contribution of lexical and semantic processes to later L1 naming. In one condition, pictures previously named in Block 1 in English or in Block 2 in Spanish were repeated to determine whether learners would reveal priming or interference. If naming in L2 requires suppression of the L1, as the previous studies with proficient bilinguals suggest, then we might not expect to see priming in the cross-language condition where a picture previously named in L2 is then named in L1. If there is global inhibition only, however, then both conditions should be slower relative to L1 naming in Block 1. In a second condition, new items were named in L1 but they were sampled from semantic categories previously presented in Blocks 1 and 2. If regulation during L2 speech planning has a category-specific scope, then we might expect that it will be more difficult to later name pictures in L1 that activate a semantic category previously associated with the L2.

Recall that the later test blocks included six individual blocks of L1 production following the L2. Due to the small number of trials from each condition appearing within the six individual
blocks, we collapsed across pairs of temporally adjacent blocks to create three larger test blocks (i.e., Blocks 3 and 4, Blocks 5 and 6, Blocks 7 and 8). These larger blocks are the units that were used for all of the statistical analyses. In addition to identifying the scope of the consequences of L2 naming on later L1 production, we hoped to identify the time course of these consequences. In the original Misra et al. (2012) paper, the same items were named in both languages, making it impossible to identify the scope of these effects. At the same time, Misra et al. found persistent inhibition throughout their experiment, suggesting that there are long lasting effects of having spoken L2. In the present study, we more precisely traced the time course of the consequences of speaking the L2 on the L1 by examining the later blocks of L1 picture naming. With the current design we can also consider different predictions about how the time course and scope might be related. In particular, we might expect the effects of global language regulation to be more extended in time than the effects of local processes that are tied to the lexical and semantic properties of the pictures that are named.

To summarize the behavioral analyses of the test blocks, the first set of analyses consisted of one-way ANOVAs with four levels of block (Block 1, Blocks 3 and 4, Blocks 5 and 6, Blocks 7 and 8) for response latency and accuracy. The second round of analyses consisted of a set of 3 x 3 ANOVAs comparing block (Blocks 3 and 4, Blocks 5 and 6, Blocks 7 and 8) and category repetition (new, new from Block 1 categories, new from Block 2 categories) and another set of 3 x 3 ANOVAs comparing block (Blocks 3 and 4, Blocks 5 and 6, Blocks 7 and 8) and lexical repetition (new, lexically-identical from Block 1, lexically-identical from Block 2).
L1 in Block 1 and in the Later Blocks (3-8)

A one-way ANOVA on response latencies examining the effect of block revealed a significant main effect of block in the analysis by subjects \[ F(3,51)=3.99, \eta^2_p=.19, p<.01; \] \[ F(3,159)=1.55, \eta^2_p=.03, p<1 \]. New pictures were named more slowly in each of the later blocks than when pictures were named during Block 1. If there were no consequences of speaking the L2 on subsequent L1 production, response latencies should have been roughly the same in Block 1 and the later blocks. Since participants named pictures more slowly during all of the later blocks, this suggests that there were long-lasting consequences of speaking the L2 on the L1. This result is not consistent with the hypothesis that learners could recover when the task provided sufficient time to measure recovery. Rather, the results show that the L1 was consistently delayed after speaking the L2. In the analysis of accuracy, the main effect of block was not significant \[ F(3,51)=1.18, \eta^2_p=.07, p<1; F(3,159)=1.16, \eta^2_p=.02, p<1 \].

![Figure 2. Mean Response Latency (ms): Block 1 and new pictures during the later blocks.](image-url)

The consistency in the pattern of slowed L1 naming latencies when new pictures were named in the test blocks is noteworthy. This pattern of results seems most compatible with the presence of a global inhibitory mechanism for the L1 after speaking the L2. It is also important
to remember that the later test blocks were mixed with respect to whether the pictures were new, new from old categories, or lexically-identical repetitions, meaning that there were essential differences between the study and test blocks. Previous studies that examined the consequences of speaking the L2 for the L1 also included a lesser mixture of new and old items (e.g., Branzi et al. 2014) and found evidence for L1 slowdown. Because the pattern was observed for studies that vary in the proportion of new and old items, it suggests that L1 slowing does not to depend on the degree of mixing in the later L1 test blocks. It is quite possible that there are consequences of the composition of the block, but the basic phenomenon of delayed naming in L1 following L2 appears to be reliable across a range of conditions.

**Analyses of new items vs. new items from previously named categories (Blocks 3-8)**

In the later test blocks of the experiment, two types of new items were presented. One set was entirely new. The other included pictures of new items from semantic categories that had been presented in Blocks 1 and 2. We observed a pattern suggesting global L1 effects when completely new items were named. Here, we ask if regulation of the L1 affects category-specific items. The ANOVA conducted on naming latencies revealed a main effect of category repetition \([F(1,17)=3.99, \eta^2_p=.20, p<.05; F(2,104)=14.59, \eta^2_p=.22, p<.01]\). Post-hoc paired-sample t-tests indicated that participants named new pictures from Block 2 categories faster than entirely new pictures \([t(17)=3.93, p<.01]\). There was no difference between new pictures from Block 1 categories relative and entirely new pictures \([t(17)=1.79, p=.09]\).
Figure 3. Magnitude of the priming (ms): New pictures from repeated categories.

For the accuracy analysis, the main effect of category repetition was significant
\[ F(1,17)=3.61, \eta_p^2=.18, p<.05; F2(2,104)=288.46, \eta_p^2=.13, p<.05 \]. Post-hoc paired-sample t-tests indicated that participants named new pictures from Block 1 categories and new pictures from Block 2 categories more accurately than entirely new pictures \[ t(17)=-3.44, p<.01; t(17)=-2.76, p<.01 \].

The presence of stronger facilitation for pictures from Block 2 categories suggests that there are consequences of category membership during speech planning. We suspect that the observed pattern of facilitation for pictures named in L1 from categories previously named in L2 reflects L2 learners’ limited proficiency. Data from Block 2 showed that learners named less than half of the pictures in Spanish correctly. It is possible that L2 learners strongly activated semantic information in the attempt to lexicalize the meaning of the pictured object to its L2 name. Strong activation of the semantics of pictures presented during Spanish naming may have induced greater priming of the category than naming in English. Similarly, past evidence has also shown that semantic interference is greater when L2 learners translate categorized lists of words into the L2 than when they translate categorized words into the L1 (e.g., Kroll & Stewart, 1994),
suggesting that semantic category information may be especially accessible when learners attempt to speak the L2. The process of activating semantic category information may, in turn, activate the L1 names of the pictures. Therefore, we attribute the facilitation observed for new pictures from Block 2 categories to increased priming of the semantic categories and the L1 translations of the words they are attempting to retrieve in the L2.

**Analyses of new items vs. lexically-identical repetitions from Blocks 1 and 2 (Blocks 3-8)**

In this analysis, we examined how repetitions of pictures that were lexically-identical to pictures named during Blocks 1 and 2 influenced L1 production in the later test blocks. The pattern for these literal repetitions was opposite to the one seen for new items from old categories. For semantically related new items, there was more priming from Block 2 (Spanish) than from Block 1 (English). The ANOVA performed on response latencies revealed a significant main effect of lexical repetition $[F(2,34)=9.79, \eta_p^2=.37, p<.001; F(2,104)=305.77, \eta_p^2=.86, p<.001]$. Further paired-sample t-tests indicated that participants named pictures that were repeated from Block 1 faster than new pictures $[t(17)=5.09, p<.001]$. Participants did not name repeated pictures from Block 2 faster than new pictures $[t(17)=1.10, p=.286]$.

![Figure 4. Magnitude of the priming (ms): Lexically-identical repetitions.](image)
For repetitions of lexically-identical pictures presented at study, there was more priming for lexically-identical pictures from Block 1 than from Block 2. If the inability to retrieve the name of the picture in L2 in Block 2 produced activation of the L1 alternative, then we might have predicted priming for lexically-identical pictures from both Blocks 1 and 2. The priming might have been stronger for Block 1 where the pictures were also named in English, but the implicit naming in Block 2 should have produced some priming. The absence of priming for lexically-identical pictures from Block 2 suggests that the L1 names of the objects were suppressed.

If learners activated the L1 name of the picture when they were attempting to retrieve the L2 name, we might expected that on some proportion of trials, there might be errors of naming that reflect an error of language. That is, on some trials, they may actually speak the L1 name itself. To evaluate this hypothesis, we examined the proportion of errors that were errors of language. Out of the total errors (1334), only three were errors of language, produced by a single speaker. This result converges with previous evidence demonstrating that proficient bilinguals produce very few language errors during lexical production, a pattern that is true for both young adult bilinguals and older bilinguals (e.g., Gollan, Sandoval, & Salmon, 2011). The result reported here suggests that even learners, who are much more vulnerable to intrusions from the L1 than proficient bilinguals, do not overtly speak the L1 during L2 production.

What is striking about the results shown in Figure 5 is that for Blocks 3-4 and 5-6, there was no facilitation for items previously named in Spanish. Because the pictures themselves were literally the same from study to test, the absence of any facilitation for lexically-identical pictures from Block 2 suggests that another process of interference countered the effect. The absence of facilitation for lexically-identical pictures from Block 2 replicates results from previous studies.
that have examined the consequences of speaking the L2 on the L1 (e.g., Misra et al., 2012; Van Assche et al., 2013). A question of interest then is whether there are mechanisms of L1 recovery that enable learners to recover from inhibition and benefit from the repetition priming. To address this question, we examined the amount of facilitation at each test block. Response latencies revealed an interaction between Block and lexical repetition that was reliable by-items, but not by-subjects [$F1(4,68)=2.49, \eta_p^2=.13, p=.05; F2(4,208)=520.35, \eta_p^2=.91, p<.001$]. The interaction indicated that repeated pictures from Block 2 were named slower than new pictures in the immediate test block after L2 production and the test block that followed that one. However, during the last L1 block (Blocks 7 and 8) participants began to experience facilitation. Thus, when there is sufficient time within a task to examine L1 production, the L1 does appear to recover.

In the accuracy analysis, the main effect of lexical repetition was marginally significant by subjects, but significant by items [$F1(2,34)=3.81, \eta_p^2=.18, p=.06; F2(2,104)=288.46, \eta_p^2=.36, p<.001$]. There trend indicated that participants were facilitated by repeated pictures from Block 1, but were not facilitated by repeated pictures from Block 2. In general, the behavioral measures suggest that there were costs at the lexical level. Interestingly, response latencies were much more sensitive to costs at the lexical level than the accuracy. This is an interesting finding, since it suggests that the consequences of speaking the L2 on the L1 might be less apparent in the analysis of accuracy because of ceiling effects for the highly skilled L1. In the sections that follow, we turn to the event-related potential data to ask if there is converging evidence across multiple measures for consequences of speaking the L2 on the L1.
ERP Analyses

Like the analyses of the behavioral data, the ERP analyses first explored the modulations observed when the L1 and the L2 were spoken during Blocks 1 and 2. In the subsequent analyses, the ERP modulations were examined for evidence of L1 regulation at the level of the whole language, the semantic category, and the specific lexical items named.

Comparing L1 and L2 in the two study blocks: Block 1 vs. Block 2

We examined the ERP waveforms during Blocks 1 and 2 to compare the patterns elicited in response to L1 and L2 naming. In the behavioral analyses comparing L1 and L2 naming, we found the predicted pattern of slower naming latencies and poorer accuracy in the L2 than the L1. Based on studies of proficient bilinguals, we expected that waveforms would diverge early for L1 and L2 and continue to diverge across the entire ERP epoch (e.g., Strijkers et al., 2009). The ERP data from Strijkers et al. (2009), comparing L1 and L2 picture naming for proficient bilingual speakers, is shown in Figure 6. Unlike the design of Strijkers et al. (2009), in the present study L1 and L2 naming were performed within subjects.

![Figure 5. Grand average waveforms for L1 (dark line) and L2 naming (light line) from Strijkers et al. (2009). *Note that the data reflect a between-subjects manipulation.](image-url)
In the first set of analyses, we focused on differences between L1 and L2 speech planning processes in the N200 (200-270 ms), an early ERP component. For the N200, at the midline, the main effect of block did not reach significance, although there was a trend for an interaction between block and electrode \( F(3, 51)=2.83, \eta^2_p=.14, p=.09 \). The trend revealed that Block 2 elicited less negativity in the waveform than Block 1 at the posterior electrodes (PZ, OZ). At the medial-lateral sites there were no significant main effects or interactions. However at the lateral-lateral sites, there was a significant two-way interaction between block and electrode \( F(2, 34)=6.87, \eta^2_p=.29, p<.05 \). ANOVAs performed on each electrode to follow up this interaction indicated that there was a marginal trend showing reduced negativity in the waveform during Block 2 relative to Block 1 at the parietal electrodes \( F(1, 17)=4.35, \eta^2_p=.24, p=.05 \). Since many studies have reported differences that extend relatively late into the ERPs, we also examined the N400 window (300-450 ms). For the N400, at the midline, there were no significant main effects or interactions. Similarly, there were no significant main effects of interactions at the medial-lateral or lateral-lateral sites. This pattern differs from the one reported by Strjikers et al. (2009) for highly proficient speakers. It also differs from the behavioral pattern that was observed behaviorally in the present study.
Figure 6. Grand mean waveforms comparing Block 1 and Block 2 at electrode CZ.

The observation that the ERPs did not reveal differences between the L1 and L2 is surprising if we assume that there are large differences in the skill associated with speaking the L1 and the L2. This finding is also counterintuitive since more proficient bilinguals who are more skilled at speaking the L2 show robust differences in ERPs comparing lexical production in the L1 and the L2. The presence of very small differences for L2 learners provides compelling evidence that the requirement to speak the L1 or the L2 influences brain and behavior in different manners. One possibility is that the ERPs are sensitive to early aspects of speech planning, whereas behavioral measures are an aggregate of early and late aspects of speech planning. More precisely, if the locus of L1 regulation during speech planning is late then this might explain why differences emerged in behavioral measures, but not in the ERPs.

**Examining the scope and time course of the consequences of speaking the L2**

**L1 in Block 1 and in the Later Blocks (3-8)**

Using the temporal precision of ERPs we compared the L1 before and after speaking the L2. In the first analysis, ANOVAs were performed to compare the mean amplitudes of the
waveform during Block 1 (L1 study) to completely new pictures that were named during the Blocks 3 and 4, Blocks 5 and 6, Blocks 7 and 8 (L1 test). ANOVAs were computed separately for the N200 and N400 components and separately across each electrode grouping (midline, medial-lateral, and lateral-lateral). For the N200, at the midline, there were no significant main effects or interactions. At the medial-lateral electrodes, there was a marginally significant main effect of block \([F(3, 51)=2.24, \eta_p^2=.12, p=.08]\). In addition, at the lateral-lateral electrodes, there was a marginally significant main effect of block \([F(3, 51)=2.64, \eta_p^2=.13, p=.06]\), indicating that the later test blocks tended to elicit greater negativity in the waveform than Block 1.

![Figure 7. Grand mean waveforms comparing Block 1 and the later blocks at the Cz for the learners speaking the L1 after the L2.](image)

For the N400, at the midline and medial-lateral sites, there were no significant main effects or interactions. At the lateral-lateral sites, there was a significant main effect of block \([F(3, 51)=10.20, \eta_p^2=.38, p<.01]\) that was qualified by a three-way interaction between block, electrode and hemisphere \([F(6, 102)=3.75, \eta_p^2=.18, p<.05]\). Follow-up ANOVAs conducted over each electrode site indicated a marginally significant interaction between block and hemisphere.
at temporal electrodes \[ F(3, 51)=2.39, \eta_p^2=.12, p=.08 \]. This trend likely indicated that all of the test blocks elicited greater negativity in the waveform relative to Block 1 in the left hemisphere. In contrast, in the right hemisphere only Blocks 5 and 6 differed from Block 1, eliciting greater negativity in the waveform. Though this is an interesting result in its own right, we will not discuss its implications here. A detailed evaluation of the time course effects, considering multiple aspects of L1 modulation over time, will be made in the general discussion.

Critically, unlike the behavioral data, the ERP record indicates no role for whole language or global inhibition in L1 following L2 naming.

**Analyses of new items vs. new items from previously named categories (Blocks 3-8)**

For the N200, there was a significant main effect of category repetition \[ F(2, 34)=5.81, \eta_p^2=.26, p<.01 \] at the midline. At the medial-lateral sites, there was a significant main effect of category repetition \[ F(2, 34)=4.31, \eta_p^2=.20, p<.05 \] and a significant interaction between category repetition and electrode \[ F(8, 136)=3.12, \eta_p^2=.16, p<.05 \]. Planned paired-sample t-tests indicated that the mean amplitude differed by category repetition at the occipital electrodes. This interaction revealed that the mean amplitude of new pictures from Block 2 categories was less negative than new pictures \[ t(17)=3.32, p<.01 \] and new pictures from Block 1 categories \[ t(17)=-2.83, p<.01 \]. At the lateral-lateral sites, there was a significant interaction between category repetition and electrode \[ F(4, 68)=6.43, \eta_p^2=.27, p<.01 \]. ANOVAs conducted over each electrode indicated that the mean amplitude of new pictures from Block 2 categories was less negative than new pictures and new pictures from Block 1 categories at the parietal electrodes \[ F(2, 34)=5.80, \eta_p^2=.25, p<.01 \].
For the N400, at the midline, there was a significant main effect of category repetition \( [F(2,34)=4.84, \eta^2_p=.37, p<.01] \). Post-hoc paired t-tests revealed that new pictures from Block 2 categories elicited less negativity than new pictures \([t(17)=-2.76, p<.05]\). The mean amplitude of new pictures from Block 1 categories was marginally different from new pictures \([t(17)=-2.00, p=.06]\). At the medial-lateral sites, there was a marginally significant main effect of category repetition \([F(2,34)=3.28, \eta^2_p=.16, p=.05]\). At the lateral-lateral sites, there was a marginally significant interaction between category repetition and electrode \([F(4,68)=2.83, \eta^2_p=.12, p=.09]\).

Like the behavioral results, the ERP findings suggest that there were consequences for the L1 that reflected regulation of category-specific information.

**Analyses of new items vs. lexically-identical repetitions from Blocks 1 and 2 (Blocks 3-8)**

We also examined how speaking the L1 after the L2 was influenced by the presence of lexically-identical repetitions. For the N200, at the midline, there was a significant main effect of lexical repetition \([F(2,34)=15.40, \eta^2_p=.48, p<.001]\) that was qualified by a significant two-way interaction between lexical repetition and electrode \([F(6, 102)=3.36, \eta^2_p=.17, p<.05]\). Follow-up
ANOVAs conducted at each electrode site showed that lexically-identical repetitions from Block 1 and lexically-identical repetitions from Block 2 elicited less negative waveforms than new items at FZ \([F(2, 34)=7.12, \eta^2_p=.30, p<.01]\), CZ \([F(2, 34)=14.64, \eta^2_p=.46, p<.001]\), PZ \([F(2, 34)=20.06, \eta^2_p=.54, p<.001]\), and OZ \([F(2, 34)=12.12, \eta^2_p=.42, p<.001]\). ERPs revealed no difference between lexically-identical repetitions from Block 1 and Block 2, FZ \([t(17)=-.37, p=.72]\), CZ \([t(17)=-.80, p=.43]\), PZ \([t(17)=-1.14, p=.27]\), and OZ \([t(17)=-.30, p=.77]\). At the medial-lateral and lateral-lateral sites, there were no significant main effects or interactions.

![Figure 9. Grand mean waveforms for the new and the lexically-identical repetition conditions at Cz for the learners speaking the L1 after the L2.](image)

For the N400, at the midline, there was a marginally significant main effect of block \([F(2, 34)=2.62, \eta^2_p=.13, p=.09]\). A significant main effect of lexical repetition was found \([F(2, 34)=10.16, \eta^2_p=.37, p<.001]\). Furthermore, there was a significant interaction between lexical repetition and electrode \([F(6, 102)=3.13, \eta^2_p=.16, p<.1]\). ANOVAs performed over each electrode indicated that lexically-identical repetitions from Block 1 and Block 2 elicited less negativity in the waveform than new pictures at CZ \([F(2,34)=9.09, \eta^2_p=.35, p<.01]\), PZ \([F(2,34)=14.37, \eta^2_p=.46, p<.001]\), and OZ \([F(2,34)=9.24, \eta^2_p=.35, p<.01]\). At the medial-lateral
sites, there was a significant main effect of lexical repetition \( F(2,34)=7.64, \eta_p^2=.31, p<.01 \) that was qualified by a significant interaction between lexical repetition and electrode \( F(8,136)=3.10, \eta_p^2=.15, p<.05 \). Separate ANOVAs conducted over each electrode indicated that lexically-identical repetitions from Blocks 1 and 2 produced less negativity than new items at central \( F(2,34)=10.78, \eta_p^2=.33, p<.001 \), parietal \( F(2,34)=9.74, \eta_p^2=.36, p<.001 \), and occipital electrodes \( F(2,34)=7.82, \eta_p^2=.35, p<.01 \). By and large, the ERP data for the repeated pictures did not reveal costs. The general pattern was facilitation, suggesting that the early indices of speech planning revealed by the ERPs diverge from behavioral measures of speech planning. Behavioral measures may reflect a mixture of both early and later planning processes, whereas ERPs may be more sensitive to early perceptual/conceptual processes that are required for picture naming.

**Interim discussion: Experiment 1**

In Experiment 1, we sought evidence for the mechanism that enables learners to speak the L2 by examining the consequences of speaking the L2 for the L1. Increasing evidence suggests that when proficient bilinguals speak the L2, there are consequences for L1 production. We predicted that acquiring the ability to regulate the L1 would be even more critical for L2 learners than for proficient bilinguals. When learners completed the modified blocked picture naming task, we observed extended consequences of speaking the L2 on subsequent L1 picture naming. In addition, this experiment also addressed important issues regarding the scope and time course of L1 regulation. The scope of L1 regulation could be restricted to specific words in the lexicon (lexically-specific), words belonging to a particular semantic cohort (category-specific), or extend to the whole language (global).
Behavioral measures demonstrated evidence for consequences at multiple levels of language control. First, facilitation was virtually eliminated when identical pictures from Block 2 were named subsequently in the L1 during the later test blocks, in which repetition priming should have been observed. This finding is important because it shows that L2 learners are affected by local inhibitory control, a consequence that has been consistently found when proficient bilinguals plan speech. We also observed modulation of the L1 at the category-specific level as a consequence of speaking the L2. A category-specific effect was present when learners named new pictures from categories previously named in the L1 and the L2, such that only pictures from categories previously named in the L2 were facilitated. The modulation here could reflect activation of both the L1 and L2 lexical alternatives once semantic category information becomes available, a sequence that is probably biased in favor of the L1. Thus, the weaker priming of the L1 categories appears to be a consequence of language regulation used to resolve activation of the L1. New pictures were also modulated by speaking the L2, suggesting there were global consequences of speaking the L2 on the L1. Furthermore, we found evidence for a relationship between the scope and time course of the consequences of speaking the L2 on the L1. Whereas local effects diminished by the latest blocks, the behavioral measures demonstrated that global effects persisted throughout the entire task.

ERPs revealed different patterns of L1 regulation than behavioral measures. Behaviorally, there were consequences of speaking the L2 on the L1 that suggested a mixture of inhibition and facilitation. The ERPs, however, demonstrated patterns that suggested there was primarily facilitation. On the basis of the behavioral data we expected facilitation for lexically-identical repetitions from Block 1, but not facilitation for lexically-identical repetitions from Block 2. The ERPs during the N200 and N400 time windows revealed less negativity in the
waveforms when repeated pictures from Block 2 were named (facilitation). This result contrasts with Misra et al.’s (2012) ERP findings, where increased negativity was found in the N200 component (inhibition) when repeated pictures were named in the L1 after speaking the L2. Although we did identify modulation of an N200-like component in the ERPs, the repetitions did not elicit increased negativity relative to completely new pictures. Multiple design aspects differed between Misra et al.’s study and the present study, including the degree to which new and repeated pictures were mixed in the test blocks. Because priming was always observed for old items relative to new items in the ERPs, we suspect that the category and lexical repetition effects at the N200 reflect mismatch detection processes similar to those that have been reported in ERP studies of visual novelty (e.g., Folstein & Van Petten, 2008).

L2 proficiency is another factor that could have contributed to the discrepancies between studies. A set of findings from multiple domains of language processing suggest that L2 proficiency influences the degree to which ERP and behavioral measures align. For example, previous studies of language processing in L2 learner populations has demonstrated dissociations between behavioral and ERP measures in lexical comprehension and sentence processing. McLaughlin, Ousterhout, and Kim (2004) found that novice L2 learners’ brain activity, as measured through ERPs, could discriminate between a newly acquired L2 within hours of classroom instruction. However, when the behavioral performance of the very same learners, they did not find any evidence that the L2 learners were able to discriminate words in the L2. Similarly, Tokowicz and Macwhinney (2005) found that when intermediate-level L2 learners processed certain non-native structures embedded in L2 sentences, ERP responses demonstrated sensitivity to violations of grammaticality, but behavioral measures did not. The present findings also support the idea that during early stages of L2 learning ERPs and behavioral measures
diverge. It also suggests that various levels of language processing, including speech planning, are affected by L2 proficiency in similar ways.

Experiment 1 provided evidence that the approach of examining the consequences of attempting to speak the L2 for the L1 is a useful method for studying the L2 speech planning processes of adult second language learners. Because the L2 learners were unskilled in speaking the L2, they were not able to name many of the pictures in Spanish. This raises the question of whether or not the learners were actually sensitive to the immediate requirement to speak the L2 or were essentially functioning as monolingual speakers. Consequences of speaking the L2 were observed, suggesting that learners did not name pictures as though there were functionally monolingual. If learners were immune to the effects of attempting to speak the L2, then facilitation should have been observed in all of the conditions associated with priming. Behaviorally, differential effects of priming were found for pictures associated with the L1 and the L2. In addition, behavioral measures revealed patterns of picture naming suggesting long-lasting inhibition. Such findings are difficult to accommodate under the assumption that subsequent speech in the L1 was not influenced by the attempt to speak the L2.

**Experiment 2: L2 learners and monolinguals speaking only the L1**

Experiment 1 examined the immediate consequences of speaking L2 on the L1 to provide insight into regulatory mechanisms underlying L2 speech planning at a relatively early stage of L2 proficiency. In Experiment 2, we asked whether there are enduring consequences of language regulation during speech planning for learners that can be observed even in the absence of the immediate requirement to speak the L2. If so, one might expect that enduring consequences of regulating the L1 during speech planning would distinguish learners’ L1 performance from that of monolingual English speakers. If there are not enduring consequences of L1 regulation,
extending to contexts in which speech is planned in the L1 alone, then L2 learners and monolinguals should demonstrate similar patterns of L1 production. Experiment 2 was designed to adjudicate between these two alternatives and provide additional evidence that immediate requirement to speak the L2 was the source of the patterns observed in Experiment 1.

The major finding from Experiment 1 was that behavioral indices of speech production revealed inhibition where priming was expected. This finding is compatible with the claim that L2 learners recruit inhibition when they are required to speak the L2. In Experiment 2, we used the same blocked picture naming task performed in Experiment 1, allowing us to determine if the inhibitory effect that eliminated priming resulted from the requirement to speak the L2. A clear prediction is that monolingual English speakers naming pictures in their dominant L1 will demonstrate priming when pictures bearing repeated lexical and category information are named. Similarly, when L2 learners produce speech in the dominant L1, they should demonstrate priming for pictures bearing repeated lexical and category information. In other words, when L2 learners do not face the immediate requirement to speak the L1 they should function like monolinguals.

Alternatively, L2 learners might experience changes to their native language as a result of frequent negotiation of cross-language activation during speech planning. Experiment 1 provided evidence that under the immediate requirement to speak the L2, modulation of the L1 occurs. In addition, the time course of L1 modulation was shown to be long-lasting, suggesting that even for highly L1 dominant learners the L1 does not easily recover. With frequent and persistent modulation of the L1, the dominant L1 may no longer resemble that of a monolingual, even when learners are only required to speak the L1. Recent fMRI studies of speech planning suggest bilinguals experience increased demands on lexical production when they are speaking.
the L1 alone (e.g., Palomar-García, 2015; Parker-Jones et al., 2012; Zou et al., 2012). That is, relative to monolinguals, increased activity in regions in the brain associated with retrieval interference (e.g., Parker-Jones et al., 2012) and executive control (e.g., Palomar-García et al., 2015) are found when bilinguals plan speech in the L1 alone. If L2 learners are affected by processes that create consequences for speech planned in the L1 alone, then behavioral measures might reveal costs. For example, learners might be generally slower to initiate speech in the L1. This pattern of production has been observed when proficient bilinguals plan speech and interpreted as a frequency-driven disadvantage in bilingual production in the Weaker Links Account (e.g., Gollan, Montoya, Cera, & Sandoval, 2008). Costs might also be revealed as less priming when pictures containing repeated information are named.

Like Experiment 1, we used a general strategy of examining patterns of L1 production during initial study and later test blocks. Since the study blocks (Blocks 1 and 2) consisted of new items named entirely in English, they can be thought of as baseline conditions of L1 production. Effects repetition priming, the effects most relevant to the main hypotheses, will be assessed by examining L1 production in the later test blocks.

Method

Nineteen L2 learners of Spanish and 18 monolingual speakers who were students at Penn State University participated in the study. L2 learners were all native speakers of English who had acquired intermediate-level knowledge of Spanish. To screen for differences in linguistic and cognitive ability, participants completed the language history questionnaire, English and Spanish lexical decision tasks (LDTs), Operation Span, and the Flanker task. Table 4 shows the participant characteristics. A set of t-tests were done to assess differences between the L2 learners and monolinguals who participated in Experiment 2. Independent t-tests indicated that
there were no differences in age ($t(35)=.33, p=.74$) nor level of education ($t(35)=-.01, p=.99$) between groups. As expected, the monolinguals had lower L2 ratings than the learners ($t(35)=-8.70, p<.001$). There was a marginally significant difference in L1 self-ratings ($t(35)=-2.02, p=.05$). However, a $d'$ analysis on data the English LDT data revealed no significant group differences ($t(35)=.81, p=.45$). Significant differences in performance on the Flanker task were found. The Flanker effect, the standard measure of Flanker performance, did not differ between groups. However, learners responded faster than monolinguals in the Flanker Congruent and Control conditions ($t(35)=-2.87, p<.01$ and $t(35)=-4.24, p<.001$, respectively). In the main analyses, we performed analyses without using Flanker performance in Congruent and Control conditions as covariates. In a separate set of analyses, we examined the influence of individual differences in inhibitory control, as indexed by Flanker performance, on picture naming performance.

The L2 learners who participated in Experiment 2 were also recruited with the aim that they would have similar levels of linguistic and cognitive ability as the L2 learners who participated in Experiment 1. Independent t-tests comparing the two groups of learners indicated that there were no differences in age ($t(35)=-.05, p=.96$) nor level of education ($t(35)=.10, p=.92$) between groups. Self-rating of L1 proficiency and L2 proficiency did not differ between groups ($t(35)=-.97, p=.34$ and $t(35)=1.15, p=.26$, respectively). The two groups performed comparably on the Flanker task.

**Materials**

The materials were identical to those used in Experiment 1.

**Procedure**
The procedure was nearly identical to Experiment 1, with the exception that picture naming was performed entirely in English (L1) for both groups. In order to prevent L2 learners from purposefully engaging Spanish throughout the task, the experimenter emphasized that the task was to be performed entirely in English at the beginning of the testing session.

**Results**

**Behavioral data**

For the data analyses, behavioral results were cleaned using the same set of criteria as Experiment 1. Errors (4%), outliers (2%), and technical errors (2%) were excluded from the data of L2 learners speaking the L1 alone. Errors (18%), outliers (.6%), and technical errors (0.50%) were excluded from the data of monolinguals.

**Comparing L1 in the two study blocks: Block 1 vs. Block 2**

Recall that L2 learners and monolinguals named pictures entirely in English during both of the study blocks. Pictures were new in Block 1 and a distinct set of new pictures were named in Block 2. Therefore, there is no reason to expect differences between Blocks 1 and 2.

ANOVAs performed on response latencies revealed that the main effect of block failed to reach significance in the by-subjects analysis, but was significant in the by-items analysis \([F1(1, 35) = .01, \eta_p^2 = .00, p > 1; F2(1, 106) = 75.98, \eta_p^2 = .19, p < .001]\). In addition, there was a significant main effect of group \([F1(1, 35) = 6.32, \eta_p^2 = .15, p < .05; F2(1, 106) = 25.55, \eta_p^2 = .22, p < .001]\). L2 learners named pictures approximately 100 ms faster than monolinguals. Furthermore, the interaction between block and group \([F1(1, 35) = .13, \eta_p^2 = .00, p < 1; F2(1, 106) = 43.95, \eta_p^2 = .29, p < .001]\) reached significance in the by-items analysis, but not in the by-subjects analysis. This interaction revealed that L2 learners were equally fast at naming pictures during
Blocks 1 and 2. However, monolinguals were 70 ms slower to name pictures in Block 2 than Block 1.

![Figure 10](image)

(A) Mean Response Latency during Blocks 1 and 2. (B) Mean Accuracy during Blocks 1 and 2.

In the accuracy analysis, a significant interaction between block and group was found by items, but not by subjects [$F(1, 35) = 2.03, \eta^2_p = .03, p < .01; F(1, 106) = 18.63, \eta^2_p = .15, p < .001$]. The interaction indicated that monolinguals named pictures more accurately during Block 1 than Block 2, but the L2 learners named pictures more accurately during Block 2 than Block 1.

In the set of analyses examining naming during the study blocks, we observed significant performance differences across groups. L2 learners named pictures faster than monolinguals. In addition, monolinguals tended to name pictures slower in the second study block than the first study block. Though differences observed in study are not critical to the main hypotheses, they are nonetheless informative. It is possible that L2 learners and monolinguals differed in the speed of L1 naming because of differences in cognitive control. As noted earlier, learners appeared to be advantaged in cognitive control, as indexed by Flanker performance. We speculate that learners are beginning to experience consequences of bilingualism on cognitive control that enable sophisticated mechanisms of self-regulation to develop. That is, when learners are aware that they are not required to speak the L2, they may up-regulate L1 speech production processes.
Based on this assumption, learners should be able to down-regulate the L1 in anticipation of speaking the L2. Interestingly, during Block 1 naming, L2 learners who named in the L1 after the L2 were significantly slower to initiate speech than learners who named in the L1 alone. Taken together, the results suggest that components of cognitive control, including self-regulation, may be recruited by learners during speech planning.

**Examining the scope and time course of priming**

In the previous set of analyses, we analyzed naming at study under conditions in which monolinguals and L2 learners named pictures entirely in the L1. L2 learners and monolinguals showed some differences in naming at study, which suggests there may be some consequences for speech planned in the L1 alone at this relatively early stage of L2 learning. However, it is likely that these consequences are distinct from those observed when L2 learners were required to speak the L2. In the next sections, we examined naming during the test blocks when L2 learners and monolinguals named speech in the L1 alone. Recall that lexical repetitions, new pictures from previously named categories, and completely new pictures were included within each of the later test blocks. One goal of comparing monolinguals’ and L2 learners’ performance at test was to examine potential changes to L1 production that could emerge from extended consequences of L1 regulation. If there are extended effects of L1 regulation, affecting speech planning in the L1 alone, these effects might be observed as changes in sensitivity to semantic and lexical priming. Another goal was to compare the performance of learners who named in the L1 alone to learners who named in the L1 after the L2 during the later test blocks. This would enable us to determine whether the requirement to immediately speak the L2 produces distinct consequences for subsequent speech in the L1. We expected that monolinguals and L2 learners would experience priming when they named lexical repetitions and new pictures from previously
named semantic categories. If there are consequences that distinguish learners from monolinguals, they still may resemble monolinguals in the sense that they are sensitive to semantic and lexical priming. In other words, we expected that inhibitory components, eliminating or reducing priming, are a unique consequence observed when the L2 must be actively spoken.

**L1 in Block 1 and in the Later Blocks (3-8)**

Like Experiment 1, a set of analyses were performed to compare naming during Block 1 to naming new items during the test blocks. When learners spoke the L1 after the L2, they named new items more slowly, suggesting global L1 regulation. The analyses reported here will enable to determine if the pattern was a consequence of global regulation or reflected the contribution of other factors (i.e., the mixture of new and old items at test). A set of 4 (block) x 2 (group) mixed ANOVAs were conducted on response latencies and accuracy. In the analysis of response latencies, a significant main effects of block was found $[F1(3, 105)= 6.32, \eta_p^2=.15, p < .01; F2(2, 210) = 6.09, \eta_p^2=.05, p < .01]$. Picture naming was slower during the test blocks than Block 1. The interaction between block and group did not reach significance. A main effect group was found $[F1(1, 35)=5.99, \eta_p^2=.15, p < .05; F2(1, 106) = 84.43, \eta_p^2=.44, p < .001]$, indicating once again that L2 learners named pictures faster than monolinguals.
Analysis of the accuracy revealed a significant effect of block \([F(3, 105)=5.41, \eta^2_p = .13, p < .05; F(2, 210) = 1.17, \eta^2_p = .01, p > .05]\) and a marginally significant effect of group \([F(1, 35)=3.34, \eta^2_p = .09, p = .08; F(1, 105) = .94, \eta^2_p = .01, p < 1]\). Participants named pictures less accurately during the test blocks than Block 1. The main effect of group revealed that L2 learners named pictures less accurately than monolinguals. Although learners named pictures less accurately than monolinguals, the differences were slight. The results suggest that there are not extended consequences for L2 learners when they speak the L1 alone. Monolinguals and L2 learners did differ in the speed of L1 naming, but more importantly, both groups were slower when they named new pictures at test than during Block 1. This presents a challenge to the interpretation of results from Experiment 1. In Experiment 1, we attributed the increase in naming latencies from Block 1 to the test blocks to the presence of global regulatory mechanisms.
when the L1 is spoken after the L2. To address this, we compared the effects observed when new items across Experiments 1 and 2 in a set of post-hoc analyses.

**Analyses of new items vs. new items from previously named categories (Blocks 3-8)**

Two questions were addressed by examining L1 production when new pictures from repeated categories were named. One question concerns whether or not learners and monolinguals differ in sensitivity to category priming. A related, but separate question concerns whether learners who named in the L1 alone and learners who named in the L1 and L2 were affected by different processes when new pictures from repeated categories were named. So far, there is no evidence that L2 learners show extended consequences when producing speech in the L1 alone that distinguish them from monolingual speakers. Therefore, we predicted that L2 learners and monolinguals would demonstrate similar levels of priming. A set of 3 (block) x 3 (category repetition) x 2 (group) ANOVAs were performed on the response latencies and accuracy. In the analysis of response latencies, a main effect of group was found \[F1(1, 35)= 6.56, \eta_p^2 = .16, p < .05; F2(1, 106) = 45.55, \eta_p^2 = .30, p < .001\], indicating that revealed that L2 learners named pictures faster than monolinguals. A main effect category repetition was observed, indicating that participants named new pictures from Block 1 and 2 categories faster than completely new pictures \[F1(2, 70)= 8.87, \eta_p^2 = .20, p < .05, \eta_p^2 = .20, p < .05; F2(2, 212) = 1.57, \eta_p^2 = .02, p < .01\]. There was no difference in the amount of priming for new pictures from Block 1 categories and new pictures Block 2 categories. In addition, the interaction between group and category repetition did not reach significance. A significant main effects of block was found \[F1(2, 70)= 4.39, \eta_p^2 = .11, p < .05; F2(2, 212) = 4.31, \eta_p^2 = .04, p < .05\], indicating that response latencies increased across the later blocks. However, there was a marginally significant interaction between block and group \[F1(2, 70)= 2.95, \eta_p^2 = .08, p = .06; F2(2, 212) = 1.59,\]
The interaction indicated that L2 learners named pictures equally fast during all test blocks, but monolinguals named pictures slower during Blocks 5 and 6 than Blocks 3 and 4, and then appeared to recover during Blocks 7 and 8.

Figure 12. (A) Magnitude of the priming for category repetitions in the later blocks: Monolinguals naming L1 alone. (B) Magnitude of the priming for category repetitions in the later blocks: L2 learners naming L1 alone.

For the analysis of accuracy, there was a significant main effect of category repetition \( [F1(2, 70) = 16.75, \eta_p^2 = .32, p < .001; F2(2, 212) = 12.16, \eta_p^2 = .10, p < .001] \), indicating that participants named new pictures from Block 1 and Block 2 categories more accurately than completely new pictures. There was no difference in the priming for new pictures from Block 1 and Block 2 categories. The main effect of category repetition was qualified by a significant interaction between group and category repetition \( [F1(2, 70) = 3.84, \eta_p^2 = .10, p < .05; F2(2, 212) = 3.49, \eta_p^2 = .03, p < .01] \). Monolinguals named new pictures faster than L2 learners, but the groups did not differ in how quickly they named new pictures from repeated categories.

The results suggest that L2 learners do not experience changes in sensitivity to category priming when they speak the L1 alone. Instead, the results showed that learners and monolinguals were equally sensitive to category priming. New pictures from Block 1 categories
and new pictures from Block 2 categories produced similar levels of priming when learners produced speech in the L1 alone, whereas learners who spoke the L1 after the L2 showed differential effects of category priming. For learners who spoke the L1 after the L2, priming was observed when new pictures from Block 2 categories were named, but no priming was observed when new pictures from Block 1 categories were observed. The results reported here suggest that inhibitory processes during L1 speech planning are exclusive to contexts in which the L1 is spoken after the L2.

Analyses of new items vs. lexically-identical repetitions from Blocks 1 and 2 (Blocks 3-8)

We observed robust category priming when L2 learners and monolinguals planned speech in the L1 alone. The analyses performed on lexical repetitions parallel those that were performed on category repetitions. Here, we asked whether or not learners and monolinguals differ in sensitivity to lexical priming. We also examined patterns of lexical repetition to determine whether the consequences observed when learners spoke the L1 after the L2 were due to inhibition or other factors. A set of 3 (block) x 3 (lexical repetition) x 2 (group) ANOVAs were performed on the response latencies and accuracy. In the analysis of response latencies, there was also a significant effect of group \([F(1, 35)=6.75, \eta^2_p = .16, p < .05; F(2(1, 106) = 1.04, \eta^2_p = .01, p < 1]\), indicating that L2 learners named pictures significantly faster than monolinguals. There was a main effect of block \([F(1, 70)= 8.54, \eta^2_p = .20, p < .01; F2(2, 212) = 0.99, \eta^2_p = .01, p < .05]\), such that participants’ response latencies increased from Blocks 3 and 4 to Blocks 5 and 6, but then decreased during Blocks 7 and 8. Furthermore, a main effect of lexical repetition \([F(2, 70)=35.23, \eta^2_p = .50, p < .001; F2(2, 212) = 12.16, \eta^2_p = .10, p < .001]\) was found, indicating that lexically-identical pictures from Block 1 and Block 2 were named significantly faster than new pictures. There was no difference in the amount of facilitation...
between lexical repetitions from Block 1 and Block 2. The interaction between lexical repetition and group did not reach significance.

![Graph A](image1.png)  ![Graph B](image2.png)

Figure 13. (A) Magnitude of the priming for lexical repetitions in the later blocks: Monolinguals naming L1 alone. (B) Magnitude of the priming for lexical repetitions in the later blocks: L2 learners naming L1 alone.

In the accuracy analysis, there was a main effect of lexical repetition \(F(2, 70)=30.73, \eta_p^2=.47, p < .001; F(2, 212)= 23.67, \eta_p^2=.18, p < .001\), indicating that participants named lexically-identical pictures more accurately than new pictures. No other main effects or interactions were significant.

As predicted, monolinguals and L2 learners experienced priming when lexically-identical repetitions were named in the later blocks. We did not find an interaction between lexical priming and group, suggesting that learners do not experience extended consequences that affect speech when it is planned in the L1 alone. In Experiment 1, we observed differential priming for lexical repetitions from Block 1 and 2. Lexical repetitions from Block 1 produced priming, but
lexical repetitions from Block 2 did not produce any priming. The absence of priming suggested that a strong inhibitory component countered the facilitation from naming lexical repetitions. Since priming was found for both repetitions when learners are aware that they do not have to speak the L2, this result confirms the presence of a local inhibitory component when L2 learners speak the L2.

**ERP Data**

ERP recording and analysis was performed identically to Experiment 1, except that the factor of group was also entered as a between-subjects variable into all of the analyses. For the L2 learners who spoke the L1 alone, 14.49% of trials were rejected after excluding trials with errors and artifacts (17%, 13%, 14%, 14%, and 14% for Block 1, Block 2, Blocks 3 and 4, Block 5 and 6, and Block 7 and 8 respectively and 27%, 13%, 16%, 12%, and 12% for new, new from Block 1 categories, new from Block 2 categories, lexical repetitions from Block 1, and lexical repetitions from Block 2 respectively). For the monolinguals, 12.03% of trials were rejected after excluding trials with errors and artifacts (7%, 7%, 14%, 10%, and 14% for Block 1, Block 2, Blocks 3 and 4, Block 5 and 6, and Block 7 and 8 respectively and 13%, 14%, 16%, 12%, and 10% for new, new from Block 1 categories, new from Block 2 categories, lexical repetitions from Block 1, and lexical repetitions from Block 2 respectively). Based on visual inspection the time windows selected for the N200 and P200 were 200-270 ms and 300-450 ms respectively. In general, we predicted that the behavioral measures would be a more sensitive measure for detecting changes to L1 production than the ERP measures. In Experiment 1, the behavioral measures were sensitive to changes in semantic priming whereas the ERPs were not. The behavioral measures also demonstrated the presence of an inhibitory component when lexical repetitions were named, but the ERPs did not. One explanation is that the measures are
differentially influenced by early and late aspects of speech planning. ERPs, in contrast, may be most sensitive to effects at the earliest stages of speech planning. Behavioral measures then, can be understood as the aggregate of early and late processes, which may reflect priming and inhibition. Therefore, the dissociation is quite logical. At the point of articulation, the consequences of priming, cross-language activation, and language regulations converge. Given these assumptions, we can ask whether the widespread effects of priming observed at the neural level when learners spoke the L1 after the L2 are due to earlier speech planning processes having greater weight for the neural record. These earlier processes, which we suspect are related to conceptual matching, are expected to produce similar patterns of priming when monolinguals and L2 learners plan speech in the L1 alone.

Comparing L1 in the two study blocks: Block 1 vs. Block 2

The behavioral data suggested that there were some differences in L1 naming when monolingual and L2 learners named pictures during the study blocks. However, we hypothesized that the ERPs would reveal similar patterns when L2 learners and monolinguals produced speech in the L1. For the N200 component, there were no significant effects at the midline, but significant effects were found at the medial-lateral sites and the lateral-lateral sites. At the medial-lateral sites, there was a main effect of group \([F(1,35)=4.27, \eta^2_p=.52, p < .05]\), indicating that L2 learners generated less negative-going waveforms than monolinguals. In addition, a significant interaction between block and hemisphere was found \([F(1,35)=5.62, \eta^2_p=.015, p < .05]\), indicating that in the left hemisphere Block 2 elicited less negativity than Block 1 in the left hemisphere, but in the right hemisphere Block 2 elicited greater negativity than Block 1. At the lateral-lateral sites, a significant two-way interaction between block and hemisphere \([F(1,35)=7.33, \eta^2_p=.18, p < .05]\) , a marginally significant interaction between block and
electrode \( [F(1,35) = 3.49, \eta_p^2 = .10, p = .06] \), and a three-way interaction between block, hemisphere, and electrode \( [F(2,70) = 5.90, \eta_p^2 = .15, p < .01] \) were found. Further examination of the three-way interaction indicated that at the right hemisphere Block 2 elicited greater negativity than Block 1, but at the left hemisphere there was no difference in the mean amplitude of the waveform during Block 1 and Block 2. Moreover, the three-way interaction revealed that the effect was maximal over the parietal electrode.

For the N400 component, at the midline, there was a significant interaction between block and electrode \( [F(3,105) = 3.57, \eta_p^2 = .09, p < .05] \), demonstrating that Block 1 elicited greater negativity than Block 2. At the medial-lateral sites, there was a marginally significant interaction between block and electrode \( [F(3, 105) = 3.30, \eta_p^2 = .09, p = .05] \), indicating that Block 1 elicited greater negativity in the waveform than Block 2. At the lateral-lateral sites there was a significant interaction between block and electrode \( [F(2, 70) = 4.52, \eta_p^2 = .11, p < .05] \) that was qualified by a significant three-way interaction between block, hemisphere and electrode \( [F(2, 70) = 3.74, \eta_p^2 = .10, p < .05] \). Further examination of the three-way interaction revealed that increased

Figure 14. (A) Grand mean waveforms during Blocks 1 and 2: Monolinguals naming in the L1 alone. (B) Grand mean waveforms during Blocks 1 and 3: L2 learners naming in the L1 alone.
negativity for Block 1 was maximal at the parietal right electrode \( [F(1, 35)=11.47, \eta_p^2=.24, p<.01] \).

A group difference was found, demonstrating overall differences in the mean amplitude when monolinguals and L2 learners named pictures during Blocks 1 and 2. These differences could be due to a number of factors, such as the differences in cognitive control that was revealed in the groups’ Flanker performance. However, it is possible that the differences which account for the neural differences observed in Blocks 1 and 2 reflect factors that were not directly assessed in the experiment. One such factor may be self-selection, which presumably influences which individuals become L2 learners and which do not.

**L1 in Block 1 and in the Later Blocks (3-8)**

In the next set of analyses, we performed ANOVAs that compared performance when new items were named during Block 1 and during the later test blocks. Behavioral measures provided evidence that monolinguals and learners were slower naming new pictures at test than naming new pictures during Block 2. This result was similar to the pattern observed when L2 learners were required to speak the L2. The main goal of the ERP analysis reported here was to determine whether the groups demonstrated similar patterns at the neural level in response to naming new items. For the N200, there was a significant main effect of block \( [F(2,70)=2.95, \eta_p^2=.08, p<.05] \) at the midline sites, indicating that the later test blocks elicited greater negativity in the waveform than Block 1. At the medial-lateral sites, there was a marginally-significant interaction between block and electrode \( [F(12,396)=2.06, \eta_p^2=.06, p=.08] \). Further separate ANOVAs by electrode revealed that there were significant block by electrode interactions at P3/P4: \( [F(3,102)=3.65, \eta_p^2=.10, p<.05] \) and O1/O2: \( [F(3,102)=5.21, \eta_p^2=.13, p<.01] \), indicating increased negativity during the later Blocks. At the lateral-lateral sites, there
was a marginally significant interaction between block and hemisphere \( F(3,99)=6.74, \eta^2_p=.17, p < .001 \). In addition, there was a marginally significant interaction between block and electrode \( F(6,210)=2.76, \eta^2_p=.08, p = .06 \) and a marginally significant three-way interaction between block, hemisphere, and electrode \( F(6,210)=2.32, \eta^2_p=.07, p = .07 \).

Figure 15. (A) Grand mean waveforms comparing Block 1 and the later blocks: Monolinguals naming in the L1 alone. (B) Grand mean waveforms comparing Block 1 and the later blocks: L2 learners naming in the L1 alone.

During the N400, there were no significant effects at the midline. At the medial-lateral site, there was a marginally significant effect of block. Planned Bonferroni-corrected paired sample t-tests indicated that Blocks 5 and 6 elicited less negativity in the waveform than Block 1. There were no other significant effects at the medial-lateral sites. At the lateral-lateral sites there was a significant three-way interaction between block, hemisphere and electrode \( F(6,216)=7.62, \eta^2_p=.18, p < .001 \). Further exploration of the three-way interaction revealed that Blocks 5 and 6
elicited less negative-going-wave forms than Block 1 and the other test blocks. The effect was
maximal at the right parietal electrode. There were no other significant effects.

Like the behavioral results, monolinguals and L2 learners demonstrate similar patterns
when new items were named. New items named during the test blocks elicited greater negativity
in the waveform than new items named during Block 1. This pattern suggests that there was
interference when pictures were named during the later blocks. The same pattern of increased
negativity at test was observed for learners who spoke the L1 after the L2, a pattern that we
attributed to a global inhibitory component. Because the same patterns were observed, regardless
of the requirement to speak the L2, the increased negativity could not be caused by global
regulatory processes. Instead, the pattern of increased negativity is likely due to the mixture of
new and old pictures in the later test blocks.

**Analyses of new items vs. new pictures from previously named categories (Blocks 3-8)**

Behavioral measures indicated similar patterns of category priming for L2 learners and
monolinguals who spoke the L1 alone, such that priming was found for new pictures from Block
1 and Block 2 categories. However, they revealed different patterns of category priming for
learners who spoke the L1 alone and learners who spoke the L1 after the L2. Learners who spoke
the L1 after the L2 did not experience priming when new pictures from Block 1 categories were
named, but learners who spoke the L1 alone showed priming for both types of category
repetitions. We examined the ERPs to determine whether converging evidence will be found at
the neural level, implicating decreases in sensitivity to category priming as a consequence of
speaking the L2.

For the N200, at the midline, there was significant main effect of category repetition
$[F(2,70)=12.04, \eta^2_p=.27, p <.001]$. Similarly, at the medial-lateral sites a main effect of category
repetition was also found \( [F(2,70)=5.72, \eta_p^2=.15, p < .01] \). The main effects observed at the midline and medial-lateral sites indicated that new pictures from Block 1 and Block 2 elicited less negativity in the waveform than completely new items. At the midline, there was a significant interaction between category repetition and electrode \( [F(6,198)=3.08, \eta_p^2=.09, p < .01] \). However, this effect was qualified by a significant three-way interaction between block, category repetition, and group \( [F(4,132)=3.54, \eta_p^2=.10, p < .01] \). Further analysis of the three-way interaction revealed that, for the monolinguals, new pictures from Block 1 and Block 2 elicited less negativity than new pictures \( (FZ [F(2,34)=5.31, \eta_p^2=.43, p < .05]), CZ [F(2,34)=12.66, \eta_p^2=.46, p < .001], and PZ [F(2,34)=7.20, \eta_p^2=.32, p < .01]) \). For the learners, new pictures from Block 1 and Block 2 elicited less negativity than new pictures at CZ \( [F(2,36)=4.51, \eta_p^2=.20, p < .05], and PZ [F(2,36)=3.84, \eta_p^2=.18, p < .05] \). A three-way interaction between block, category, and group was also found at the medial-lateral sites. The interaction indicated that, for monolinguals, facilitation was observed at C3 \( [F(2,34)=6.97, \eta_p^2=.32, p < .01] \) and P3 \( [F(2,34)=7.32, \eta_p^2=.23, p < .01] \). At the lateral-lateral sites, however, there was no interaction between category repetition and group. At these electrode sites, there was simply a main effect of category repetition \( [F(2,70)=5.72, \eta_p^2=.14, p < .01] \).
Figure 16. (A) Grand mean waveforms for the new and the new from repeated categories conditions for monolinguals speaking the L1 alone. (B) Grand mean waveforms for the new and the new from repeated categories conditions for L2 learners speaking the L1 alone.

For the N400, at the midline, there was a significant main effect of category repetition \[F(2,70)=6.71, \eta_p^2=.16, p<.01\] that was qualified by a significant two-way interaction between category repetition and electrode \[F(6,210)=3.71, \eta_p^2=.10, p<.05\]. ANOVAs conducted separately over each electrode indicated that there was a significant effect of category repetition at electrodes FZ \[F(2, 70)=5.84, \eta_p^2=.14, p<.01\], CZ \[F(2, 70)=7.20, \eta_p^2=.17, p<.01\], and PZ \[F(2, 70)=6.18, \eta_p^2=.15, p<.01\], but not at electrode OZ. At the medial-lateral sites, there was a significant main effect of category repetition \[F(2,70)=3.43, \eta_p^2=.09, p<.05\], indicating that new pictures from Block 1 and new pictures from Block 2 elicited less negativity in the waveform than completely new pictures. At the lateral-lateral sites, there was a main effect of category repetition \[F(2,70)=6.06, \eta_p^2=.15, p<.01\], that was qualified by a significant two-way interaction between category repetition and electrode \[F(4,140)=3.79, \eta_p^2=.10, p<.05\]. Follow-up ANOVAs, conducted separately over each electrode indicated that new pictures from Block 1
and Block 2 categories elicited significantly less negativity than completely new pictures at temporal electrodes.

Facilitation was observed when monolinguals and L2 learners new pictures from Block 1 and Block 2 categories. Thus, neither behavioral measures nor ERP measures provided evidence suggesting enduring consequences for learners that influence sensitivity to category priming. For L2 learners who named pictures in the L1 after the L2, priming was observed only for new pictures from Block 2 categories. Because the priming was absent in the other category repetition condition, it suggest that inhibitory components are involved in L2 speech planning. Interestingly, ERPs revealed that monolinguals showed more extensive topographic effects of category facilitation than L2 learners. This may, in part, reflect differences in the speed of L1 naming. Behavioral measures provided clear evidence that L2 learners named pictures faster in than monolinguals. Previous evidence suggests that naming speed affects the ERP waveform patterns during L1 picture naming (e.g., Lagrano, Valente, & Perret, 2012). Lagrano et al. (2012) found that fast individuals demonstrated increased negativity in an N200 time window (200-330 ms) relative to slow individuals. If the result of the present study reflected speed differences, then it would provide converging evidence that speed of naming influences conceptual-semantic processes.

**Analyses of new items vs. lexically-identical repetitions from Blocks 1 and 2 (Blocks 3-8)**

We examined the ERP record to address whether or not learners and monolinguals differ in sensitivity to lexical priming. For the N200, at the midline, there was priming for lexically-identical repetitions, such that lexically-identical repetitions elicited less negative-going waveforms than completely new pictures \[F(2,70)=11.84, \eta_p^2=.26, p <.001\]. Furthermore, there was a marginally significant interaction between lexical repetition and electrode \[F(6,210)=2.37,\]
$\eta_p^2=.07, p=.08$, indicating that the repetition priming was maximal at the central-parietal electrodes. At the medial-lateral sites, there was a significant main effect of lexical repetition $[F(2,70)=8.52, \eta_p^2=.21, p<.01]$. There was a significant main effect of lexical repetition $[F(2,70)=8.91, \eta_p^2=.21, p<.01]$ at the lateral-lateral sites. Additionally, there was a significant interaction between block and hemisphere $[F(2,70)=3.87, \eta_p^2=.11, p<.05]$. There were no other significant main effects or interactions.

![Figure 17](image)

Figure 17. (A) Grand mean waveforms for the new and the lexical repetition conditions for monolinguals speaking the L1 alone. (B) Grand mean waveforms for the new and the lexical repetition conditions for L2 learners speaking the L1 alone.

For the N400, at the midline, there was a significant main effect of lexical repetition $[F(2, 70)=5.19, \eta_p^2=.13, p<.01]$, indicating that lexically-identical repetitions from Block 1 and Block 2 elicited less negativity in the waveforms than new pictures. In addition, there was a significant interaction between lexical repetition and electrode $[F(6, 210)=3.85, \eta_p^2=.10, p<.05]$, indicating. Significant effects of lexical repetition were found over CZ $[F(2,70)=4.32, \eta_p^2=.11, p<.05]$, PZ
F(2,70)=7.59, ηp²=.18, p<.05], and OZ [F(2,70)=7.04, ηp²=.17, p<.05]. At the medial-lateral sites, there were no significant main effects or interactions. At the lateral-lateral sites, there was a significant two-way interaction between lexical repetition and block [F(4, 140)=2.91, ηp²=.08, p<.05], indicating that lexically-identical repetitions from Block 1 and Block 2 elicited significantly more negativity than new items during Blocks 5 and 6. Furthermore, there was a significant three-way interaction between lexical repetition, block, and electrode [F(8, 280)=4.39, ηp²=.11, p<.01]. ANOVAs conducted over each electrode revealed that the interaction between lexical repetition, block, and electrode was significant at electrodes T7/T8 [F(4,40)=7.45, ηp²=.18, p<.01].

ERPs revealed patterns that were consistent with facilitation, mirroring the patterns observed in the behavior. Lexically-identical repetitions primed naming, indicated by the reduction in negativity during the N200 and N400 time windows. Critically, there was no difference in the amount of facilitation observed when learners and monolinguals named lexical repetitions.

Discussion

In the current study, ERP and behavioral measures were used to identify the mechanisms that enable L2 learners to speak their L2. We evaluated the mechanisms of language control using an extended block picture naming task which included multiple blocks of L1 production. Learners were asked to name pictures in a blocked fashion in the L1-L2-L1 order, as in previous studies that have examined mechanisms of speech planning in proficient bilinguals (e.g., Misra et al. 2012; Branzi et al., 2013). This approach, which focuses on speech in the dominant language, was expected to be ideal for studying the speech planning of L2 learners. L2 learners are notoriously poor at speaking words in the L2. Indirectly examining L2 speech planning by
focusing on changes to the L1 that occur in the context of attempting to speak L2 enabled us to overcome past limitations. It was hypothesized that because of the large difference in the skill associated with speaking L1 and L2, inhibition of the dominant L1 would be critical for speaking the L2 as a learner. Previous research generally favors the hypothesis that even proficient bilinguals recruit inhibition when they speak the dominant language after the L2. Therefore, we expected even stronger evidence for L2 learners who do not have nearly the same skill speaking L2 as proficient bilinguals.

We found support for the hypothesis that L2 learners recruit long-lasting inhibition when they speak the L1 after the L2, particularly when lexical repetitions originally named in the L2 were later named in the L1. For these repetitions, response latencies were longer than when new pictures were named. In contrast, lexical repetitions originally named in the L1 that were named later in the L1 were facilitated, producing shorter response latencies than new pictures. Because these pictures were presented as identical repetitions across the blocks, a manipulation known to produce large facilitation, the results suggest that there was inhibition of the L1 during planning of the L2. Substantial inhibition would have to be present to counter the facilitation that should have been present in the behavioral measures of response latency when repeated pictures from the L2 were named.

Proficiency and the development of language regulation

The present results provide insight into the development of language control processes during bilingual speech planning. In particular, the results address the issue of whether beginning and late stages of L2 proficiency are characterized by qualitatively different forms language regulation. Two alternative models have been used to evaluate the mechanisms of language
regulation during bilingual speech planning. The Inhibitory Control model (Green, 1998) argues that bilinguals regulate their languages via inhibition, and inhibition is proportional to the amount of conflict induced by the language. A key prediction from this model is that the more dominant will be inhibited to a greater extent than weaker language. Another model, which we refer to as the mental firewall model (Costa & Santesteban, 2004), claims that inhibition is only required for bilinguals that are unbalanced in L1 and L2 proficiency. When bilinguals’ two languages are more closely matched in proficiency they can use language-selective mechanisms to plan speech without competition from the other language occurring. Critically, both models would predict that L2 learners inhibit the dominant language to a strong degree when they attempt to speak the L2.

One aspect of the mental firewall model has posed a challenge for its particular developmental account of language regulation. When balanced bilinguals perform trial-by-trial language switching, the dominant language appears to slow down. The presence of L1 slowdown is extraordinary because it demonstrates that the dominant L1 is spoken more slowly than the weaker L2 when both languages must be spoken. In effect, this pattern of results demonstrates that the speech planning of proficient bilinguals is affected by a form of global inhibition. This finding has caused controversy over the accuracy of the mental firewall model’s predictions, as it suggests that inhibition of the L1 is exploited by all bilinguals. The present results suggest that further revision of accounts of bilingual speech planning may be needed. The results showed that L2 learners engage inhibition, but the inhibitory effects we observed were less extensive than those observed when proficient bilinguals plan speech. The overall speed of L1 naming was no slower when L2 learners named pictures in the L1 after the L2 than when leaners named in the L1 alone. Therefore, the evidence presented here suggests that, learners at the beginning stages
of L2 development are not affected by global inhibition. Rather, the present findings favor the idea that learners recruit local inhibition.

Multiple findings in the recent literature on proficient bilingual speech planning are consistent with the notion of global mechanisms of inhibition during speech planning. Why might L2 learners’ speech planning be characterized by local inhibitory components and not global inhibition? L2 learners are highly dominant in the L1 which implies that the L1 is fairly stable and not dramatically influenced by the brief requirement to speak the L2. In other words, L1 stability may preclude global regulation when the L2 must be spoken. Immersed L2 learners, who have a clear need to engage the L2 for production more frequently than non-immersed learners, have been shown to experience changes to L1 stability (e.g., Linck et al., 2009). Therefore, it is possible that immersed learners may differ from learners with classroom experience only when asked to perform the very same blocked picture naming task, showing global and local regulation. Future research is needed to investigate whether classroom and immersed learners show different inhibitory consequences when required to speak the L1 after the L2.

The scope and the time course of language regulation

The current results also extend existing accounts of the different types of inhibitory components by addressing issues of scope and time course. Recent studies have provided evidence for multiple components of inhibition that vary in scope and time course. The blocked production task has provided evidence for long-lasting mechanisms of inhibition. Using the blocked picture naming task, Misra et al. (2012) found ERP evidence that relatively proficient bilinguals engaged inhibition. Bilinguals completed two blocks of picture naming in each language. When bilinguals spoke the L2 during the first two blocks of naming, an inhibitory
pattern was observed in the ERPs for the subsequent L1 blocks. Since the inhibitory pattern was observed throughout both of the subsequent L1 blocks it suggests that the bilinguals did not immediately recover the L1. Because the L1 did not recover, even when several trials of naming in the L1 were produced after speaking the L2, the results of Misra et al.’s study suggested that the whole language itself must have been suppressed. In other words, if only a few words had been inhibited while speaking the L2, one would expect that these words could be easily recovered and the L1 would stabilize. However, since the same pictures were named in the L1 and L2 picture naming blocks, it was impossible to determine whether the inhibition was long-lasting and affected the whole language.

Like Misra et al. (2012), we used the blocked picture naming task to study mechanisms of regulation when the L1 was spoken after the L2. However, we included additional manipulations that allowed us to tease apart the components that may differ in time course, components that may vary in scope, and ask the question of how effects at each level of scope may vary over time. Specifically, we included pictures in the subsequent L1 blocks that lexically-identical repetitions, like Misra et al. We also included new pictures from previously named categories and completely new pictures, manipulations of scope that were not present in the original Misra et al. study. Like Misra et al., we found evidence for local, or lexically-specific inhibition. In addition, we found evidence for category-specific language regulation when leaners spoke the L1 after the L2. Learners named new pictures from categories previously named in Spanish (L2) faster than new pictures, but did not name new pictures from categories previously named in English faster than new pictures. We speculated that this mechanism is driven by the particularly weak skill that learners have in L2 lexical production. Because speaking the L2 is effortful and slow, semantics may be strongly activated even when L2
learners cannot actually articulate the L2 word they intend to say. In the process of activating semantics though, it is likely that the L1 translation equivalent will be activated, since it has more direct links to meaning (e.g., Kroll & Stewart, 1994). Thus, the category-specific regulation observed in the current study may be a component unique to L2 learners. Future work will be needed to fully examine how proficiency and other factors influence category-specific regulation.

Interestingly, regulation at the lexically-specific and category-specific levels of scope was long-lasting in time course. However, lexically-specific regulation diminished within the temporal limits of the task. Category-specific regulation did not diminish within the time permitted by the blocked picture naming task. This suggests that not only are there multiple mechanisms of control that vary in scope, but they may also vary in time course, revealing different patterns of L1 recovery.

**Native language changes in speech production**

In the current study, we examined evidence for native language changes during speech production. Evidence that bilinguals experience changes to the native language exists has been demonstrated in multiple domains, including, but not limited to speech production. For example, Dussias and Sagarra (2008) showed that immersed bilinguals, who had been living in an L2-speaking country for several years, used L2 syntactic parsing strategies when reading L1 sentences for comprehension. The immersed bilinguals’ performance deviated from a group of monolinguals who did not speak an L2. In addition, a group of non-immersed bilinguals did not use L2 syntactic parsing strategies, suggesting that immersion was the source of the change to the syntactic parsing processes. Similarly, immersed bilinguals frequently report, on the basis of their phenomenology, that they have lost access to words in the L1. It is possible that changes
that occur in the context of L2 immersion reflect mechanisms of inhibition that are very long-lasting. Linck et al. (2009) conducted a study examining the consequences of immersion for L2 learners. L2 immersed learners performed the standard verbal fluency task, naming exemplars from different categories in the two languages. They found that immersed learners produced fewer exemplars in the L1 than non-immersed, classroom learners. Linck et al. attributed the poorer performance in the L1 to native language inhibition. The studies of L1 changes in the context of L2 immersion suggests that a mechanism of inhibition may exist that modifies the L1, distinguishing bilinguals from monolinguals when they use the L1.

When L2 learners named pictures in the L1 after the L2, we found evidence for long-lasting regulation. Costs were observed that included the elimination of repetition priming. Priming was diminished for several blocks after the L2 was spoken, suggesting that even for highly L1 dominant bilinguals, the L1 does not immediately recover from inhibition. Based on this observation, it was of interest whether L2 learners would show extended consequences of L1 regulation, distinguishing them from monolinguals when they spoke only the L1. We hypothesized though, that highly L1 dominant L2 learners do not engage L1 regulation unless the L2 has been activated first. L2 learners and monolinguals who spoke the L1 alone were virtually identical in L1 production, demonstrating strong evidence for facilitation when pictures had been repeated. Therefore, at the early stages of L2 development the L1 does not undergo change that distinguishes learners from monolinguals. It appears that for L2 learners, consequences of speaking an L2 are exclusive to when the L2 is explicitly required.

**The relationship between speech planning processes and domain-general executive control**

There is increasing evidence demonstrating that bilinguals experience changes in the domain of executive control that distinguish them from monolinguals. Typically, it has been
reported that bilinguals outperform monolinguals on tasks of executive control ((Bialystok, 2005; Bialystok, Craik, & Freedman, 2007; Bialystok Craik, Klein, & Viswanathanm, 2004; Costa, Hernandez, & Sebastián-Gallés, 200; but see Valian, 2015). This has led to the hypothesis that it is the control of linguistic interference that confers bilinguals with expertise in domain general executive functions. The Bilingual Advantage hypothesis (e.g., Bialystok, Craik, Green, & Gollan, 2009), remains an issue of debate. One particular aspect of the hypothesis is yet to be addressed. There is no consensus as to which component of bilingual language experience produces the remarkable changes observed to bilinguals’ executive control. Executive control could be recruited when bilinguals read, listen to, and speak words in their two languages because all of these aspects of language use are likely to involve some degree of conflict between the two languages. A clear distinction may be made between mechanisms of comprehension and production if we assume the bottom-up versus top-down nature of the selection processes will yield different consequences of cross-language activation. Indeed, there is emerging evidence that the time course of inhibition during comprehension is short-lived (e.g., Blumenfield & Marian, 2011; Martín, Macizo, & Bajo, 2010), whereas in production they are long-lasting (e.g., Misra et al., 2012). A tentative hypothesis is that speech production may be an especially important domain for training bilinguals’ inhibitory control, leading to advantages in domain general inhibition relative to monolinguals.

Another way to frame the issue is to ask whether individual differences in inhibition are equally predictive of bilinguals’ and monolinguals’ speech planning. We can think of the recruitment of inhibition during bilingual language processing as an adaptation to the constraints under which bilinguals regularly use language (e.g., Green & Abutalebi, 2014). Bilinguals may face unique situational pressures that require flexibility to exist between the L1 and L2, as in
code-switching contexts, or that interference be prevented from an unintended language, as in single language contexts. Thus, one would expect a stronger coupling between cognitive control and speech planning for bilinguals than monolinguals. In the current study, we found some evidence for differences in the ability to exploit cognitive control resources between the L2 learners and the monolinguals. L2 learners demonstrated a speed advantage, relative to monolinguals, in the Flanker task. Specifically, we found that L2 learners responded faster than monolinguals to trials in the Control and Congruent conditions. These results are compatible with the previous literature on bilingual cognitive advantages since speed advantages have already been reported in numerous studies (e.g., (Bialystok, 2006; Martin-Rhee & Bialystok, 2008).

We conducted a post-hoc analysis on the data from the current study to address whether there are differences in the relationship between inhibition and speech planning for monolinguals and L2 learners. Using a composite of the Flanker Control and Flanker Congruent latency measures, we performed regression analyses on the behavioral data from the blocked picture naming task. We asked, for L2 learners naming in the L1 after the L2, would individual differences in inhibitory control predict the magnitude of the lexical repetition priming. Recall that when repetitions of pictures previously named in Spanish did not produce the expected repetition priming for learners who spoke the L1 after the L2. The learners were significantly slower to name repetitions previously named in Spanish, suggesting inhibition. We predicted that the inhibition when Spanish repetitions were named would be influenced by the inhibitory resources that the L2 learner had. L2 learners with less inhibitory resources were expected to show greater inhibition because they are less efficient at overcoming interference between languages. Learners with more inhibitory resources (i.e., faster on Flanker task) would be more
likely to shown facilitation, since they can negotiate language interference more efficiently. We performed the analogous analyses with L1 learners who named in the L1 only and monolinguals to address whether individual differences in inhibition predicted the magnitude of lexical priming. We pulled the same priming measure, RTs for lexical repetitions from Block 2 out of the data for monolinguals and L2 learners speaking the L1 alone. Note that for monolinguals and L2 learners speaking the L1 alone, there should not be any linguistic interference since only the L1 was spoken. Interestingly, both groups of L2 learners were faster than monolinguals in the Flanker conditions, but did not differ significantly from each other on these measures. Because both groups appeared to be advantaged relative to the monolinguals, it suggests that the individual difference measure might also predict the performance of the learners who named L1 only. It might be expected that learners who named in the L1 alone who had less inhibitory resources (i.e., slower in Flanker task) would experience less priming, whereas those with greater inhibitory resources (i.e., faster in Flanker task) would experience greater priming.

For the regression analyses, a composite was formed by transforming the RTs from Flanker Control and Congruent conditions using guidelines followed by Pivneva, Palmer and Titone (2012). Since the composite is based on RTs, it reflects the speed by which a participant responded during the Flanker task. When the composite was a large positive number, it indicated that the participant was slow at performing the task. When the composite was a large negative number, it indicated that the participant was fast at performing the task. Composite values that approached zero indicated that the participant performed at average speed for the distribution from which they were sampled. Regressions were fitted separately for the monolinguals, L2 learners naming in the L1 alone, and L2 learners naming in the L1 after the L2. Additionally, separate regressions were computed on the magnitude of the priming (RT lexical repetition
minus RT new item) during each of the three test blocks that were included in the blocked picture naming task. Since the learners were otherwise matched on proficiency, cognitive and demographic variables we performed a series of simple linear regression with only the Flanker composite as a predictor variable.

Examination of the $R^2$ statistics for each group of participants, showed that the composite did predict priming during picture naming for the L2 learners, but only L2 learners who spoke the L2 during the picture naming task. However, the composite did not predict variance in priming at all of the test blocks. For L2 learners who named pictures in the L1 after the L2, the composite Flanker variable was a marginally significant predictor of lexical priming during Blocks 3 and 4 [$\Delta R^2 = .19, F(1, 17) = 3.74, p = .07$]. But, the variable did not predict performance during Blocks 5 and 6 [$\Delta R^2 = .07, F(1, 17) = 1.18, p < 1$] and Blocks 7 and 8 [$\Delta R^2 = .04, F(1, 17) = .67, p < 1$]. For L2 learners who named pictures in the L1 alone, the composite Flanker variable did not significantly predict lexical priming during Blocks 3 and 4 [$\Delta R^2 = .09, F(1, 18) = 1.63, p < 1$], Blocks 5 and 6 [$\Delta R^2 = .04, F(1, 18) = .61, p < 1$], nor Blocks 7 and 8 [$\Delta R^2 = .05, F(1, 18) = .67, p < 1$]. For monolinguals, the composite Flanker variable did not significantly predict lexical priming during Blocks 3 and 4 [$\Delta R^2 = .07, F(1, 17) = 2.05, p < 1$], Blocks 5 and 6 [$\Delta R^2 = .03, F(1, 17) = .47, p < 1$], nor Blocks 7 and 8 [$\Delta R^2 = .04, F(1, 17) = .70, p < 1$].
Figure 18. Regression plot of the correlation between the magnitude of lexical priming during picture naming and the Flanker composite score.

The results of the analysis addressing the relationship between inhibition and speech planning for L2 learners demonstrate a modest relationship. As predicted, learners who had greater cognitive control, responding faster in the Flanker task, engaged greater inhibition of the repetitions previously named in Spanish. Thus, a key finding was that individual differences in Flanker performance only predicted the performance of L2 learners who spoke the L1 after the L2. The link between speech planning and domain general inhibition was only revealed for L2 learners who spoke the L1 after the L2. For this group, L2 learners who were slow at responding in the Flanker task were more likely to produce inhibition when lexical repetitions were spoken. In contrast, learners who were faster at responding in the Flanker task were more likely to produce priming. No relationship between the individual difference measure and the amount of priming/interference was found for learners who named in the L1 alone.

Although the experiments conducted within the current study improved our understanding of the development of language control at early stages of bilingualism there were important limitations. Learners were aware that they were recruited for the study because of their
status of speakers of multiple languages. This might have caused them to anticipate the requirement to speak the L2 at the outset of the task. Critically, this anticipatory effect may be present for the learners who were actually instructed to speak the L2 and the learners who the experimenter instructed to speak only the L1. We suspect that anticipatory modulation of the L1 did occur at the outset of the task, since the three groups showed large differences in L1 naming latencies from Block 1, the first block of L1 picture naming. Learners who spoke the L1 after the L2 were slower than learners naming in the L1 alone. It is rather curious that one group of L2 learners would be slower than matched controls to speak their dominant language, from Block 1. The straightforward prediction is that since they were matched as closely as possible on background variables, their performance in Block 1 should have been the same. The key difference, though, is that the group of learners assigned to speak the L1 alone was informed that L2 was not required for production and the other group wasn’t. Therefore, any expectations that that group had about speaking the L2 probably influenced naming during Block 1. Interestingly, this suggests that there may be additional mechanisms of control that enable bilinguals to modulate language in an anticipatory fashion. It will be important in future work to clarify how bilinguals are able to induce anticipatory modulations of the L1 using approaches that track these processes in real-time.

In summary, the results support the hypothesis that there are immediate and long-lasting consequences of speaking the L2 on the L1 for L2 learners. To the best of our knowledge, this is the first evidence demonstrating that L2 learners’ lexical production can be investigated using the same techniques as those used to study speech planning in proficient bilingual speakers. In addition, support for the existence of a long-lasting mechanism of L1 language regulation was found. Previous studies have found long-lasting patterns of control that impacted repetition
priming. In these studies, it was not clear if the reduction in repetition priming was due to the presence of inhibition or reflected additional factors. Unlike these other studies, the present study included conditions in which the L1 was spoken alone. In the absence of the requirement to speak the L2, learners and monolinguals demonstrated robust priming evidence. Thus, it is clear that the lack of priming is due to an inhibitory component countering the facilitation that is expected when repetitions are named. In the present study, it was demonstrated that L2 learners do not show extended effects of production in the L2, distinguishing them from monolinguals when they speak the L1 alone. Individual differences in cognitive control, as indexed by the Flanker, did not reveal modulation of control during L1 alone production for L2 learners and monolinguals. Future work will consider how individual differences in other components of executive control, such as set-shifting or working memory, influence modulation of control during L2 learners’ speech planning.
Author Notes

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Chapter 5: Experiment 3- Catching inhibitory control

In the following section, I present a manuscript to be submitted for publication that contains the results and discussion of Experiments 3. Experiments 3 examined the cognitive consequences of language regulation for L2 learners using a Go/No-go picture naming paradigm. Like Experiments 1 and 2, the manuscript concludes with a brief set of remarks summarizing the main outcomes and the implications of the research. However, a summary of Experiment 3, emphasizing how it relates to the larger goals of the study are discussed in the general conclusion. In the discussion I interpret the results with respect to the following questions: Do L2 learners show evidence for differences in cognitive control when compared to monolingual speakers? Is there evidence that control engaged for the sake of regulating the L1 during speech planning affects domain-general cognitive control?
Catching inhibitory processes during speech planning on the fly

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Abstract

When bilinguals prepare to speak, words from both languages compete for selection. Inhibition of the dominant language (L1) has been hypothesized to resolve cross-language competition. The consequences of inhibition during speech planning may generalize beyond language itself. A hypothesis gaining support is inhibition during bilingual speech planning confers bilinguals with advantages in cognitive control. However, there is virtually no evidence that directly links inhibition in bilingual speech to cognitive advantages. Additionally, little is known about the developmental trajectory of inhibitory control in second language (L2) learners. Second (L2) language speakers who are not yet proficient speaking the L2 may have a particular need to inhibit the more dominant L1. We examined these issues by using ERPs to catch inhibition on the fly. Monolinguals and L2 learners completed a Go/No-go task in which pictures were initially named and then later repeated as Go trials or No-go trials. L2 learners named pictures in the L1 after the L2. Monolinguals named in the L1 only. It was hypothesized that if learners inhibited the L1 in order to speak the L2, pictures initially named and presented later as repetitions would reveal consequences of inhibition. Both L2 learners and monolinguals demonstrated increased positivity in the P300 window (300-450 ms) for Go trials relative to No-go trials. However, L2 learners and monolinguals generated different patterns in response to repetitions that were named overtly on Go trials. L2 learners demonstrated increased positivity in the P300 for Go-repetition trials, a finding that suggest that the names of these pictures were inhibited. Monolinguals demonstrated increased positivity for Go-new trials, rather than Go-repetition trials. Differences in Go/No-go performance might reflect tuning of cognitive control for L2 learners. The results suggest that when learners plan speech in the L2, there are long lasting consequences for cognitive control.
Introduction

Within the past twenty-five years, there has been an impressive increase in the amount of research investigating bilingual language processing and cognition. In the past, it was once thought that bilinguals could function as though they were monolingual speakers of two languages. However, the evidence overwhelmingly suggests otherwise. Whenever bilinguals speak, listen to, or read words in a single language they co-activate words in the other language. Remarkably, many findings have demonstrated that the presence of two simultaneously activated languages has consequences not only for language itself, but also cognition more broadly defined. One of the most impressive findings from research conducted on bilingualism is that the brain and cognition can undergo remarkable plasticity even into adulthood.

Bilingual speech planning as a model of language plasticity

In order to produce a single word, speakers must navigate through a sequence of steps, mapping a concept to recognizable speech sounds. For healthy adult speakers, the automaticity associated with producing words in speech belies the complexity of speech planning. On the surface, speech is executed without a hitch. However, most models of speech planning agree that speakers co-activate unintended words during speech planning. For bilingual speakers, who possess at least two alternatives from each language for any given concept, parallel activation of intended and unintended words during production may be even more problematic. Empirical than monolinguals. An intuitive hypothesis proposed by some models of bilingual speech planning is that by the early stages of conceptual/semantic selection, activation of alternatives in the other language diminishes (e.g., Bloem & La Heij, 2003; Levelt, Roelofs, & Meyer, 1999). However, counter to these predictions, recent research shows that parallel activation of words in both languages often extends beyond early stages of planning. In fact, parallel activation may
persist until the phonological and articulatory information about words in both languages is active. The general view, then, is that bilinguals face frequent and persistent activation of words in both languages during speech planning (e.g., Kroll, Bobb, Wodniecka, 2006).

Recent research demonstrates that parallel activation during bilingual speech planning has far-extending consequences on language that may require mediation via recruitment of additional cognitive resources. For example, Misra, Guo, Bobb, and Kroll (2012) found evidence for long-lasting inhibitory effects when bilinguals planned speech in their two languages. In their study, bilinguals named pictures as a series of trials, blocked by the language of production (e.g., L1 or L2). The researchers hypothesized that blocking the languages in this manner, would effectively provide a cue that the bilinguals could exploit to eliminate parallel activation of words in the unintended language when the language to be spoken changed. Two groups of bilinguals named pictures. One group named pictures for blocks of pictures, first in the L1 and then in the L2 (L1-L1-L2-L2) and the other named pictures first in L2 then in the L1 (L2-L2-L1-L1). Critically, the identical pictures were shown across L1 and L2 blocks with the expectation that repetition would produce facilitation. If facilitation was not observed during the later blocks in which the language of production switched, then it would suggest the presence of an inhibitory component. An inhibitory ERP pattern was observed for the group who named in the L1 after speaking the L2, but a facilitatory pattern was observed for the group who named in the L2 after the L1. For the group who spoke L1 after L2, increased negativity was observed in the N200 component, which has been implicated in domain-general inhibition. Crucially, the inhibitory ERP pattern persisted across both blocks of subsequent L1 production, suggesting that the bilinguals did not immediately recover from the inhibition. Thus, the study demonstrated that at
least one of the mechanisms that bilinguals use to resolve the effects of parallel activation during speech planning involves long-lasting inhibition.

Evidence suggests that speech planning is a particular language domain that shows a high degree of openness to change. Indeed, it has been speculated in previous research that speech is the channel through which bilinguals exercise executive control the most. However, it is not clear whether or not special properties of speech planning are responsible for producing such enduring consequences for the L1. Parallel activation occurs during language comprehension and production. Therefore, mechanisms for controlling the two languages must be honed when listening to and reading language input as well. The critical question is whether these mechanisms share the same properties. If so, one might expect there to be enduring consequences for bilinguals when they comprehend language as well as when they plan speech. Palomar-Garcia et al. (2015) used fMRI to investigate the neural correlates of listening and picture naming in bilinguals. Bilinguals and monolinguals performed two tasks in the L1 alone, passive listening and picture naming. When the brain activity during passive listening was examined, there were no differences between bilinguals’ and monolinguals’ patterns of brain activity. However, when picture naming was examined, bilinguals activated a more extended network than monolinguals, including regions such as the precuneus, the right superior temporal gyrus, and the anterior cingulate cortex. The results demonstrated converging evidence for changes to the networks involved in L1 speech planning as a consequence of bilingualism. Critically, it provides evidence that some of the most dramatic effects of bilingualism on language processing are driven by modification of the processes responsible for speech planning.

**Bilingual cognitive advantages**
A large body of research has identified consequences of bilingualism that extend beyond language, to affect cognitive processes more broadly. The main hypothesis in this work is that there are “bilingual cognitive advantages”, meaning that bilingual language experience endows bilinguals with superior cognitive functions relative to monolinguals. The majority of the evidence supporting this claim has been found in cognitive tasks that involve some form of conflict, requiring individuals to resolve interference from competing responses/representations. The critical point in this work is that advantages are found for bilinguals, even though these tasks have nothing to do with language itself. This suggests that there are aspects of managing two languages as a bilingual that has a relation to how efficiently conflict can be resolved outside of the language domain. The specific explanation that has been given for this remarkable observation is that non-linguistic cognitive processes are exploited by bilinguals whenever they perform any linguistic function. Thus, the bilingual advantage is hypothesized to reflect a lifetime of experience recruiting non-linguistic cognitive processes for carrying out linguistic functions.

Research comparing how bilinguals and monolinguals fare on tasks involving inhibitory control is often cited as the evidence for bilingual cognitive advantages. Many studies used the Simon task to gauge the differences in bilinguals’ and monolinguals’ ability to exploit domain-general inhibitory control (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok et al., 2005; Martin & Bialystok, 2003; Martin-Rhee & Bialystok, 2008). In the Simon task, participants see different colored squares at central or peripheral locations on the computer screen. The participant is required to identify the color of the square by pressing a button. Sometimes the button that must be pressed to make a correct response aligns with the visual location of the stimulus (Congruent). Critically, the location of that button is sometimes
incompatible with the location of the stimulus (Incongruent). This mis-mapping between stimulus information and response information creates conflict. The Simon effect, the difference in response times on Incongruent and Congruent trials (Incongruent-Congruent), was the main measure taken from this task. Evidence from the Simon task has demonstrated evidence favoring the bilingual cognitive advantages hypothesis, with bilinguals showing smaller Simon effects than monolinguals. This has caused some researchers to view finding superior bilingual performance on inhibitory control tasks as the litmus test for bilingual cognitive advantages.

But some of the evidence from the Simon task, and additional tasks that are assumed to require inhibition (e.g., Flanker, Stroop, Go/No-Go, Stop-Signal), has not revealed differences in monolinguals’ and bilinguals’ abilities in inhibition. Sometimes no differences are found. Other times, differences are found in neutral conditions, in which expertise in inhibition could not be the source of advantages. This latter observation, in particular, was interpreted as a large inconsistency for the bilingual cognitive advantages hypothesis. The limitation of the hypothesis, may lie in the fact that the “advantage” was originally conceived as a one-to-one relationship between a particular aspect of bilingual language processing and a particular aspect of executive control. Due to the increasing number and diversity of findings, we now know that the relationship is more complex than initially assumed. In a critical review of research on bilingual cognitive advantages, Bialystok and Kroll (2014) argued that the logic of making inferences on the basis of tasks that target one component process of executive control is flawed. One limitation of the approach is that there is not task that examines just a single construct of executive control. A number of different cognitive mechanisms can work together to produce differences in brain and behavioral processes between monolinguals and bilinguals. Thus, research that focuses on a single explanatory route between bilingual language processing and
changes in executive control is becoming less favored. Instead, an increasingly favored interpretation of bilingual and monolingual differences is that there are multiple forms of control that may be modulated by virtue of bilingual experience. In other words, bilingualism may allow for a diverse set of resources to be exploited and used flexibly. The modulation of control from proactive to reactive states has served as an important construct in recent work on the relationship between bilingualism and cognitive control (e.g., Morales, Yudes, Gomez-Ariz, & Bajo, 2015; Zhang, Kang, Wu, Ma, & Guo, 2015)

Morales, Yudes, Gomez-Ariz, and Bajo (2015) conducted an ERP study that investigated the hypothesis that bilingualism may affect the coordination between proactive and reactive forms of executive control. According to the Dual Mechanisms of Control framework, (e.g., Braver, Paxton, Locke, & Barch, 2009), proactive control is the ability to maintain task goals in mind and prevent interference before it happens. In contrast, reactive control is the ability to update relevant task information and inhibit prepotent responses. In order to test the for differences in the ability to coordinate reactive and proactive control mechanisms, Morales et al. compared monolinguals’ and bilinguals’ performance on a version of the Continuous Performance Task (CPT, Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956) In this task, participants must respond to a sequence of letters, with the initial letter being the cue and the last letter being the probe. They are instructed that to responds “yes” when they see an X probe preceded by an A cue. They are also instructed to respond “no” when they see any other combination of cues and probes (i.e., BX, AY, and BY are “no” trials). ERPs were recorded as participants performed the task, with the prediction that modulations associated with proactive and reactive control would be indicated in windows surrounding cue and probe presentation. Specifically, they hypothesized that increased positivity during the cue-P3b, an ERP component
associated with updating and maintenance of relevant information (Polich, 2007), would indicate reliance on proactive control. They also hypothesized that increased negativity during the N2 and increased positivity during the P3a during probe presentation would indicate reliance on proactive control.

Critically, though, Morales et al. (2015) hypothesized that in order to perform the AX-CPT task most efficiently dynamic interplay between reactive and proactive control is necessary. Bilinguals were expected to experience consequences of shifting control mechanisms when processing language that would transfer to the domain of executive control, enabling them to adjust efficiently between the two components of control throughout the task. The results demonstrated that bilinguals recruited greater reactive control than monolinguals, indicated by larger P3a amplitudes on “no” probes preceded by a misleading “A” cue. But, they also differed from monolinguals in the recruitment of proactive control. Although both groups showed similar P3b cue activity on AY trials, in which the cue inaccurately predicted a “yes” response, only bilinguals did so without compromising accuracy, suggesting greater cognitive flexibility for the bilinguals.

**Linking bilingual speech planning with cognitive consequences of bilingualism**

In the previous sections, we reviewed separate findings suggesting changes to bilingual speech planning on the one hand, and changes to executive control on the other. Implicit in both lines of research is the idea that there are bidirectional influences on language and cognition as a consequence of accommodating two languages in one mind. Another line of research has aimed to make explicit connections between bilingual language processes and executive control. A new approach taken by recent studies investigating bilingual cognitive advantages directly examines
how resolution of linguistic conflict influences subsequent performance on non-linguistic tasks by capturing modulation of control in real-time.

Blumenfeld and Marian (2011) conducted an eye-tracking study that tracked modulation of inhibition during auditory comprehension in real time. To induce modulation of the L1 through the implementation of control, a manipulation was included in the auditory comprehension task that introduced lexical conflict. The researchers asked monolinguals and bilinguals to listen to an aurally presented target word and then identify the location of the target within a four quadrant visual array. A within-language distractor object that overlapped in phonology with the target object was included in the array in order to introduce competition. On the subsequent trial, a response had to be made to the quadrant that previously contained the distractor. The idea was that if the distractor location had been inhibited to enable selection of the target, then participants would be slower to respond on the subsequent trial.

Essentially this is a form of negative priming. For example, if the first trial in the sequence of contained images in the array for a “plum” and a “plug”, the expectation is that participants would experience competition selecting the word form during the course of identifying the auditory stimulus. On this first trial, the target prime “plum” is responded to and on the second trial, the button response corresponds with the location where the competitor “plug” was. The results showed that monolinguals were slower to respond on competitor priming probe trials (“plug”) compared to control trials without phonological competition (for example, when the competitor was “ant”), suggesting that they inhibited the location of the distractor stimulus. However, bilinguals were no slower identifying the location of a stimulus on the subsequent trial when it previously contained the competitor than when it previously contained a control. It can be assumed that bilinguals inhibited the competitor, just as monolinguals.
However, these findings suggest bilinguals disengage from inhibition earlier than monolinguals, suggesting that there was an additional component of control that allowed the L1 to recover. These results converge with the findings of Morales et al. (2015), suggesting that bilingual advantages may not be characterized by reliance on a single component of executive control, but the dynamic interplay between multiple components.

One implication from Blumenfeld and Marian’s study is that the presence of linguistic conflict is negotiated differently by monolinguals and bilinguals. Because the monolinguals and bilinguals performed the task entirely in the L1, it also suggests that differences in executive control did not reflect bilinguals being in a “special” mode bought about by a bilingual context. It is possible that if bilinguals were in a bilingual context while performing the auditory word recognition task they might have been even more sensitive to the presence of lexical conflict. The hypothesis that language context may modulate executive control for bilinguals is important to consider, as it provides insight into the generalizability of bilingual cognitive advantages.

Wu and Thierry (2013) asked if the immediate language context influenced how bilinguals performed a domain-general executive control task. Bilinguals performed a modified Flanker task while ignoring distractor words. The task was performed in three blocks, one block with only L1 distractor words, another with only L2 distractor words, and the other block including a mixture of L1 and L2 distractor words. ERPs were recorded simultaneously as participants performed the three blocks in the task. It was hypothesized, that if bilingual cognitive advantages are context-dependent, that modulations would be observed depending on whether L1 only, L2 only, or L1 and L2 mixed distractor words were presented. Wu and Thierry hypothesized that differential effects in the P300, a component associated with inhibition in the Flanker task (e.g. Polich, 2007; Neuhaus et al., 2010), would be observed between the three
language contexts. Incongruent trials, in which there is conflict, induce more positivity in the P300 than congruent trials. The results showed that ERP mean amplitude in the P300 for incongruent trials was reduced in the mixed compared with the monolingual blocks. Like Morales et al. (2015), the results suggest that bilinguals modulate executive control in a dynamic fashion to suit the needs of the immediate context. This finding is compatible with the more recent hypothesis of bilingual advantages stating that bilingualism affects cognition by enhancing flexibility in cognitive control.

**The current study**

We report one experiment that was conducted to examine whether persistent cross-language competition during speech planning modulates domain-general executive control. One aim was to replicate prior evidence for the presence inhibitory control mechanisms during speech planning. The question asked is whether L2 learners demonstrate consequences of emerging proficiency in an L2 in the domain of speech planning. This question was motivated by evidence from recent production studies, suggesting that regulation of the L1 is critical for bilingual speech planning (e.g., Branzi et al., 2014; Misra et al., 2012; and Van Assche, 2013). When the L1 is spoken after the L2, the dominant language appears to be suppressed. Two consequences of speaking the L2, both suggesting L1 suppression, have been reported. When proficient bilinguals speak the L1 after the L2, the L1 is produced more slowly relative to monolinguals. This global consequence has been demonstrated by examining bilinguals’ ability to name new items subsequently in the L1. The idea is that if a global mechanism suppressed the whole language, even new items would be more difficult to name in L1 after L2. For L2 learners, the
consequences of inhibition for speech planning might manifest as global effects, making them slower and less accurate to name new pictures than monolinguals.

Local consequences, affecting a restricted set of items in the lexicon, have also been demonstrated when bilinguals speak the L1 after speaking the L2. For example, Misra et al.’s (2012) study demonstrated that repetitions of words initially named in the L2 did not produce priming when they were subsequently required for naming in the L1. For repetition priming to not be present, substantial inhibition would have to be present to counter the expected facilitation. The consequences might also manifest as a local effect, reducing L2 learners’ sensitivity to lexical priming. On the basis of models of bilingual speech production, it was hypothesized that L2 learners would recruit a great deal of inhibition in order to prevent the L1 from intruding during L2 speech planning (e.g., Costa & Santesteban, 2004; Green, 1998). We predicted that L2 learners would demonstrate evidence for local or global consequences of L1 inhibition. Note, however, that the observation of local and global consequences of inhibition are not mutually exclusive (e.g., Van Assche et al., 2013).

A second aim was to examine the relationship between inhibition of the L1 during speech planning and domain general cognitive control. In the present study, Go/No-go manipulations were used to track modulation of language inhibition over time. The idea was that learners may potentially shifting from strong reliance on reactive suppressive mechanisms to less reliance on reactive control or other (non-reactive) mechanisms as they recover the L1. In previous studies (e.g., Blumenfeld & Marian, 2011) bilinguals demonstrated evidence suggesting the recruitment of sophisticated mechanisms of control that enabled them to engage inhibition when conflict was present and recover from inhibition rapidly. Similarly, Morales et al. demonstrated that bilinguals shifted more effectively than monolinguals between reliance on reactive and proactive
control mechanisms. In the current study, we used the logic of previous studies that tracked shifts between different forms of control.

Language control was expected to interact with the ability to respond in Go/No-go naming, as they draw on similar cognitive control resources. If learners strongly recruit reactive inhibition to speak the L2, then this will impact the amount of resources that will be used to make a Go or No-go response. One possibility is that Go responses will be named more cautiously or slower due to the L1 being actively suppressed. Another possibility is that No-go responses will be less effortful, because the L1 is suppressed. This is, in effect, a reversal of the canonical pattern expected for Go and No-go responses. Typically, No-go responses require great cognitive effort (as evidenced in ERPs by the N200 component). If No-go responses deviate from the canonical response, by being delayed (in RT or ERP onset) or amplified (in ERP amplitude), it would suggest that additional language control processes are influencing the Go/No-go response. However, a shift in reliance on reactive control by learners might occur throughout the task, such that the typical No-go response is observed. Thus, we aimed to track modulation of inhibitory processes during speech planning as they occurred during picture naming in a modified Go/No-go task.

Participants first performed blocked picture naming, naming pictures aloud as they appeared one-by-one on the computer. In later blocks, pictures were cued for Go/No-go naming predicted that trials in which No-go was cued would require more inhibition than Go trials. Generally, successful Go/No-go performance is characterized by increased negativity in the N200 and increased positivity in the P300 waves (e.g., Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003) for No-go relative to Go trials. New and repeated pictures were included to identify the manner in which L2 learners’ Go/No-go responses were influenced
by processes of language regulation. New pictures were included to determine if language regulation affected the ability to suppress the name of the picture (No-go) or speak the name of the picture (Go) at the global level. Repeated pictures were included to determine if language regulation affected the ability to suppress the name of the picture (No-go) or speak the name of the picture (Go) at the global level. Modulation of the N200 and P300, was expected if language regulation influenced picture naming at the global and local levels.

Methods

Participants

Eighteen monolingual speakers of English and 18 L2 learners of Spanish who were native speakers of English (L1) participated in the experiment. All participants were right-handed, had normal or corrected-to-normal vision, and no history of neurological disorder. L2 learners were native English speakers with intermediate-level proficiency in Spanish. They were all late learners who had studied Spanish since age 12 on average and had a minimum of three college semesters of Spanish instruction (mean: 5.40 semesters). They were dominant in their L1 (English) in reading, writing, speaking, spelling, and listening skills as self-reported on a language history questionnaire. Monolinguals had limited exposure to an L2 (mean: 1.80 semesters). There was no difference between participants in terms of age or L1 proficiency (self-ratings and an English Lexical Decision task, ps >.1). The groups were also matched on working memory and cognitive control (Operation Span and Flanker tasks, Ps >.1), but the L2 learners showed slightly higher scores on the English verbal fluency task (p = .08). Language and cognitive profiles for the two groups tested, including number of participants per group, mean age, mean L1 self-ratings, mean L2 self-ratings, and Operation-Span score, and verbal fluency scores can be found in Table 1 below.
Table 1. 
Participant language and cognitive profiles. Self-ratings are on a 10 point scale, in which 10 represents very high proficiency and 1 represents very low proficiency. The self-assessed index is the average of participants’ responses for each domain (reading, writing, speaking and comprehension). OSPAN scores are reported as the mean number of words recalled in the Operation Span task (Turner & Engle, 1989). Flanker score are reported as the mean Flanker effect in milliseconds (e.g., Luk et al., 2010). English and Spanish verbal fluencies are reported as the mean number of exemplars produced in the entire task. (standard deviations in parentheses).

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<th>N</th>
<th>Age</th>
<th>L1 Self-rating</th>
<th>L2 Self-rating</th>
<th>Ospan</th>
<th>Flanker</th>
<th>English Verbal Fluency</th>
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<td>L2 Learners</td>
<td>18</td>
<td>20.56</td>
<td>9.90 (0.78)</td>
<td>7.34 (0.83)</td>
<td>54 (5)</td>
<td>48 (21)</td>
<td>22 (4)</td>
<td>10 (2)</td>
</tr>
<tr>
<td>Monolinguals</td>
<td>18</td>
<td>20.11</td>
<td>9.74 (1.27)</td>
<td>2.80 (1.38)</td>
<td>51 (9)</td>
<td>41 (22)</td>
<td>20 (4)</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

Materials

One hundred and sixty-two pictures were selected for the picture naming task. Pictures were presented in three formats: line drawing, color photograph or black and white photograph format. Thus, a set of 486 picture stimuli was created. The colored and black and white photograph images were retrieved from Google Images. Line drawings were taken from the Snodgrass and Vanderwart (Snodgrass & Vanderwart, 1980) picture database and Google Images. Pictures were controlled for their dimensions, and were 400 x 400 pixels. Pictures were matched as closely as possible across conditions for the number of syllables in the picture’s name, frequency, familiarity, and number of taxonomic features, which are variables that have been found to influence picture naming latencies in past research (e.g., Alario et al., 2004; Cuetos, Ellis, & Alvarez, 1999; Snodgrass & Yuditsky, 1996).
Characteristics of Pictures and Picture Names

Notes. Blocks 1 and 2 were the same items but counterbalanced across participants, therefore means are averaged together. 

a Kučera & Francis (1967); Per million words. b Data from the MRC Psycholinguistic database (Coltheart, 1981). c Data from the English Lexicon Project database (Balota et al., 2002). McRae et al. (2005); Number of taxonomic semantic features d

<table>
<thead>
<tr>
<th>Variable</th>
<th>Blocks 1 and 2</th>
<th>Repetitions from Block 1</th>
<th>Repetitions from Block 2</th>
<th>New Items</th>
<th>p-value (F-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Syllables</td>
<td>1.6 (0.8)</td>
<td>1.6 (0.8)</td>
<td>1.5 (0.7)</td>
<td>1.7</td>
<td>.78</td>
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<tr>
<td>Frequency</td>
<td>20.5 (34.6)</td>
<td>21.1 (41.5)</td>
<td>19.9 (27.8)</td>
<td>20.6</td>
<td>.98</td>
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<tr>
<td>Familiarity</td>
<td>6.0 (3.0)</td>
<td>5.6 (3.0)</td>
<td>6.3 (3.0)</td>
<td>6.1</td>
<td>.36</td>
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<tr>
<td>Number of features</td>
<td>12.4 (5.9)</td>
<td>11.9 (6.4)</td>
<td>12.8 (5.3)</td>
<td>13.8</td>
<td>.25</td>
</tr>
</tbody>
</table>

Fifty-four pictures were assigned to be named in Block 1 and another 54 were assigned to Block 2. Half of the pictures from Blocks 1 and 2 were presented again later in Block 3 as repetitions. The other half were presented later in Block 4 as repetitions. Twenty-seven new pictures appeared in Blocks 3 and 4 each. Blocks 3 and 4 both contained 49% Go trials and 51% No-go trials.

Procedure

Participants were tested individually in a sound-proof testing room. They were seated in a comfortable chair approximately 20 inches away from a Dell computer monitor. A microphone
attached to the S-R box was placed directly in front of the participant as closely as possible without occluding their vision. In the blocked picture naming task, participants first received instruction in English on the computer screen. L2 learners were informed that a series of pictures would appear on screen and that they would name pictures during first in the L1 and later in the L2. Monolinguals were instructed that they would perform the task entirely in the L1. At the beginning of each trial, a fixation sign (+) was presented at the center of the computer screen for 500 ms. After the offset of the fixation sign, a picture was presented. Pictures were always presented with a colored frame to maintain visual consistency across the task. However, during Blocks 1 and 2, pictures were all cued to be named aloud by a green frame. During Blocks 3 and 4, pictures were randomly cued for Go and No-go naming. A red frame indicated that responses should be withheld and a green frame indicated the response should be named aloud. For all trials, the picture was presented for 1000 ms or until the participants responded. After they responded, a blank screen was presented for 1000 ms and a fixation sign appeared again. If participants did not know the name of the picture, they were instructed to be silent. Participants received 10 practice trials of English picture naming before Block 1 and 10 practice trials of before Block 2. In addition participants completed 10 practice trials of Go/No-go naming prior to Block 3. To avoid introducing potential strategies, there was no familiarization with picture names prior to testing. The pictures used during practice and experimental trials were different items.

**Behavioral Data Analysis**

Recorded picture naming responses were first transcribed and scored for accuracy. Responses that included the expected name of the picture and responses that included synonyms or close semantic relatives were counted as correct. Responses that were unrelated to the
expected picture name, responses that started with an article or hesitation, and omissions were scored as errors. Responses that the microphone did not detect were eliminated as technical errors. After trimming response latencies for correct responses that were less than 300 ms or greater than 3000 ms for both L1 and L2 trials, response latencies that were 2.5 standard deviations above or below the mean were identified as outliers and excluded from the analyses. Finally, accuracy and response latencies for correct responses were calculated. For L2 learners, errors (5%), outliers (2%), and technical errors (.3%) were excluded from the analyses. For monolinguals, errors (5%), outliers (1%), and technical errors (.1%) were excluded from the analyses. Because participants were not pre-trained on the picture names, relatively liberal criteria were used to judge whether a picture was named correctly. Items for which participants responded with an answer that was somewhat imprecise but correct (e.g., ‘‘jacket’’ for ‘‘coat’’) and pronunciation errors in L2 were marked as correct answers.

**ERP Recording and Data Analysis.**

The continuous electroencephalogram (EEG) was recorded using a 32-channel sintered Ag/AgCl electrode array mounted in an elastic cap according to the 10-20 system (QuikCap, Neuroscan Inc.). Recordings were referenced to the left mastoid during recording and re-referenced off-line to the average activity of the left and right mastoids. Electrode impedances were kept below 5 kΩ. Lateral eye movements were measured by electrodes placed on the outer canthus of each eye. Vertical eye movements were measured by electrodes placed on the upper and lower orbital ridge of the left eye. Eye recordings were later used off-line to reject contaminated trials. The electrophysiological signals were amplified using Neuroscan Synamps with a band pass filter of 0.05 to 100 Hz and a sampling rate of 500 Hz. Only trials with correct responses were included in the analyses. A pre-stimulus baseline of 150 ms and an epoch
duration of 600 ms post-stimulus were used to compute average ERPs per condition. Trials with eye movement artifacts or blinks and peak-to-peak deflections over 100 µV were rejected. A digital low-pass filter of 30 Hz (24 dB/oct) was applied when analyzing the data off-line.

Running t-tests were performed separately for monolinguals and L2 learners, comparing the mean amplitude between new No-go and new Go trials across the entire EPR epoch. Significant differences were found during a single time window, corresponding to the P300 component. The time window between 300 and 450 ms was selected for further analysis. Although visual inspection suggested there may be Go/No-go modulation of the N200, reliable differences were not found in the N200 component. Thus, ERP analyses were restricted to the P300 component.

Results

Behavioral Analysis

Learners and monolinguals naming in Block 1

If L2 learners use global control to speak the L2, then L1 naming in the L1 will appear to be suppressed for L2 learners compared to monolinguals. In the previous sections, we reviewed evidence suggesting that global regulation of the L1 occurs as a consequence of speaking the L2. However, it is also possible that the L1 might be modulated in a global manner in anticipation of speaking the L2. Learners who are not yet proficient speaking the L2 may be especially vulnerable to intrusions from the L1 and preemptively regulate the L1 to avoid speaking it when the L2 is required. Evidence for global suppression of the L1 might be present during Block 1, the initial block of L1 production. This hypothesis was tested by comparing monolinguals’ and bilinguals’ L1 production during Block 1. Univariate ANCOVA was performed on response latencies and accuracy from Block 1 to examine potential differences in monolinguals’ and L2
learners L1 production. If there were global inhibitory effects for learners speaking the L1, we expected L2 learners to name pictures more slowly and less accurately than monolinguals. In the analysis of response latencies, an ANCOVA [between-subjects factor: group (L2 learners, monolinguals); covariate: English verbal fluency] revealed a marginal main effect of group \([F(1,33)=2.96, \eta_p^2=.08, p=.09]\), such that L2 learners named pictures slower overall than monolinguals. The main effect of verbal fluency was significant \([F(1,34)=6.52, \eta_p^2=.17, p<1]\), but the interaction between English verbal fluency and group was not significant. The main effect indicated that participants with greater English verbal fluency in English were faster to name pictures in the L1.

Figure 1. Regression plot of the correlation mean exemplars produced in English Verbal Fluency and L1 picture naming during Block 1.
In the accuracy analysis, the ANCOVA did not reveal a main effect of group 
\[ F(1,33)=0.22, \eta_p^2=.01, p<1 \], nor a main effect of English verbal fluency \[ F(1,33)=0.30, \eta_p^2=.01, p<1 \].

Interestingly, the data revealed that L2 learners named pictures more slowly than monolinguals at the outset of the task, suggesting that the L1 was regulated globally in anticipation of speaking the L2. Critically, however, individual differences moderated the speed at which learners and monolinguals named pictures in the L1.

**Comparing L1 and L2 picture naming during Blocks 1 and 2**

The data from Block 1 indicated that L2 learners were modulating the L1 in anticipation of speaking the L2. Learners might be highly aware of their limited skill in speaking the L2, and so knowing in advance that they were required to speak the L2 might have prompted immediate modulation of the L1. Nevertheless, it is worth considering whether the asymmetry in learners’ L1 and L2 proficiency could also be a factor that influences later L1 production. We hypothesize that the asymmetry in the skill associated with speaking the two languages would be reflected in differences in accuracy and response times when learners speak the L1 and L2 during Blocks 1 and 2, respectively.

A set of repeated measure ANOVAs were performed comparing Block 1 and Block 2 response latencies and accuracy for the L2 learners only. In the analysis of response latencies, there was a significant main effect of Block, \[ F(1,17)=92.25, \eta_p^2=.84, p<.001 \], such that learners named pictures more slowly during Block 2 (L2) than Block 1 (L1). In the analysis of accuracy, a significant main effect of block was found \[ F(1,17)=139.64, \eta_p^2=.89, p<.001 \], indicating that learners named pictures less accurately during Block 2 than Block 1.
Figure 2. Mean response latencies and accuracy during Block 1 and 2 picture naming. Note: L2 learners spoke L1 in Block 1 and L2 in Block 2.

Critically, no differences were observed between Blocks 1 and 2 when monolinguals named pictures entirely in the L1 [for response latencies and accuracy, respectively: [F(1, 17)=, $\eta_p^2 = p<1$; F(1, 17)=, $\eta_p^2 = p<1$]. The results indicate that there is a very large asymmetry in learners’ ability to speak the L1 and the L2. Therefore, we expect the consequences of speaking the L2 to have substantial consequences on subsequent L1 production.

**Consequences of speaking the L2 for later L1 production: Naming during Blocks 3 and 4**

When proficient bilinguals speak the L1 after the L2, inhibitory consequences have been observed for the L1 (e.g., Misra et al., 2012; Van Assche, Duyck, and Gollan, 2013). One consequence suggesting the presence of inhibition is the absence of repetition priming during picture naming in the L1 (e.g., Misra et al., 2012). Like previous studies that have investigated L1 after L2 production, we used lexical repetitions to assess the presence of local inhibitory processes during L1 production following the L2. We hypothesized that for L2 learners, regulation of the L1 during speech planning would be even more critical for speaking the L2. Like Misra et al., we expect that the consequences of inhibiting the L1 would be revealed when
repeated pictures were named, showing elimination or reversal of repetition priming. Repeated pictures might be named slower than completely new pictures when L2 learners speak the L1 after the L2. For monolinguals, we expect that the typical pattern of facilitation, faster naming latencies for repetitions than new pictures, will be observed when repetitions are named. In addition, consequences of speaking the L2 on the L1 might be observed at the global level, affecting the entire language itself. If so, one might expect that learners are slower to name pictures in the L1 overall than monolinguals.

Two blocks of L1 picture naming were included after L2 production to determine whether or not learners would recover from inhibition within the time span of the task. Recall that these two later L1 blocks (Blocks 3 and 4) were identical for monolinguals and L2 learners. Therefore, the absence of facilitation for learners and the presence of facilitation for monolinguals would clearly indicate the presence of inhibition during L2 learners’ speech. It is also important to note that the two later L1 blocks (Blocks 3 and 4) were named in a Go/No-go fashion. Since repetition priming is a robust phenomenon (e.g., Barry, Hirsh, Johnston, & Williams, 2001; Cave, 1997; Cave & Squire, 1992; Mitchell & Brown, 1988), we expected that the conditions of Go/No-go naming would not eliminate the effect of repetition priming.

A set of ANCOVAs [between-subjects factor: group (L2 learners, monolinguals); covariate: English verbal fluency; within-subjects factor: lexical repetition (new, repetition from Block 1, repetition from Block 2)] were performed on response latencies and accuracies during Blocks 3 and 4. In the analysis of response latencies, the ANCOVA revealed a significant main effect of group [$F(1,33)=5.59$, $\eta_p^2=.15$, $p <.05$]. L2 learners named pictures significantly more slowly than monolinguals, after controlling for English verbal fluency [$F(1,33)=4.13$, $\eta_p^2=.11$, $p =.05$]. There were no other significant main effects or interactions.
The results indicated that L2 learners named pictures in the L1 significantly more slowly than monolinguals. Because monolinguals and learners were closely matched on a number of cognitive and linguistic skills, this result is consistent with the idea that there were unique consequences of speaking the L2 that influenced learners’ L1 production. Specifically, this pattern suggests that there were global consequences of speaking the L2 on subsequent L1 production in the later blocks. Surprisingly, repetition priming effects was not observed for either group. It was expected that speaking the L2 would eliminate priming when learners subsequently named repetitions in the L1. However, given that the monolinguals did not demonstrate the predicted pattern of repetition priming it is not clear if there were local inhibitory effects that affected repetition priming for L2 learners. We expected that the effects of repetition priming would be large for monolinguals, because typically robust facilitation from repetitions is observed during picture naming (e.g., Barry, Hirsh, Johnston, & Williams, 2001). One possible explanation for the lack of priming across the board is that there was uncertainty at the point of
naming created by performing Go/No-go. The additional decisional process may have made a greater contribution to picture naming, masking the repetition priming for both groups. One possibility, then, is that ERPs will be sensitive to repetition priming, despite the absence of priming at the behavioral level. If the uncertainty induced by Go/No-go naming has consequences for the later stages of speech planning (e.g., articulation), then it is possible that ERPs will reveal modulation by repetitions reflecting processes that correspond to the earlier conceptual stages of speech planning.

**ERP analysis**

Behavioral results suggest that learners modulated the L1 in anticipation of speaking the L2. However, it is unclear if there were any consequences of speaking the L2 for later production. Since the goal of the study was to track the consequences of speaking the L2 for the later production in the L1 and for domain-general cognitive control, the focus of the ERP analysis is limited to the later blocks. Recall two later blocks of L1 production were presented and each included Go/No-go naming. A series of repeated measures ANOVAs evaluated differences between monolinguals’ and L2 learners’ performance in the later Go/No-go as indicated by modulation of the P300 component. We used Go/No-go naming to ask whether there are consequences of L1 regulation that persist beyond the immediate context of speaking the L2 to influence domain-general cognitive control. We hypothesize that inhibition recruited during speech planning draws from domain-general cognitive resources, and will have later consequences for how L2 learners perform Go/No-go. Specifically, we predict that L2 learners will demonstrate evidence of inhibiting the names of repeated pictures that were previously spoken in Blocks 1 and 2. When these repetitions are named later as Go trials in Blocks 3 and 4 they might be more difficult to overtly produce than new items. In addition, it is possible that L2
learners will require less effort inhibiting the name of repetitions from Blocks 1 and 2 on No-go trials than they require for inhibiting new pictures cued for No-go. If so, less positivity in the no-go P300 will be observed when learners are instructed to withhold the names of repetitions from Blocks 1 and 2 relative to new pictures.

Critically, Rodriguez-Fornells, Van der Lugt, Rotte, Britti, Heinze, and Munte (2005) found such a pattern when proficient bilinguals who performed an event-related potential Go/No-go phoneme detection task. Monolinguals and bilinguals were required to press a button when a particular letter was present in the name of the pictures shown throughout the task. The task was performed entirely one language (i.e., the bilinguals L2 and monolinguals’ L1) but some pictures were included to create language incongruity for the bilinguals. Sometimes the target letter existed in the L1 translation, but not in the L2 translation that they were instructed to base their judgment on. When there was language incongruity, bilinguals showed a delayed N200 response relative to monolinguals. This suggests that the conflict induced by language altered the manner in which bilinguals made no-go responses. Similarly, we expect that L2 learners will show changes to the Go/No-go response as a consequence of speaking the L2.

**Consequences of speaking the L2 for later L1 production: Naming during Blocks 3 and 4**

As seen in Figure 4, all stimuli elicited a P300 around 300 ms, which lasted approximately 150 ms. A set of ANCOVAs [between-subjects factor: group (L2 learners, monolinguals); covariate: English verbal fluency; within-subjects factor: lexical repetition (new, repetition from Block 1, repetition from Block 2)] were performed on the P300 waveforms, comparing the performance of L2 learners to monolinguals in the later Go/No-go blocks (Blocks 3 and 4). Separate analyses were conducted over each electrode grouping (e.g., midline, medial-lateral, and lateral-lateral).
Figure 4. (A) Comparison of Go and No-go trials that were repetitions from Block 1 for L2 learners. (B) Comparison of Go and No-go trials that were repetitions from Block 1 for monolinguals. (C) Comparison of Go and No-go trials that were repetitions from Block 2 for L2 learners. (D) Comparison of Go and No-go trials that were repetitions from Block 2 for monolinguals. (E) Comparison of Go and No-go trials that were New for L2 learners. (F) Comparison of Go and No-go trials that were New for monolinguals.
All of the analyses reported were performed using English verbal fluency scores as a covariate. At the midline, there was a marginally significant interaction between block, go/no-go naming, and the English verbal fluency score \[ F(1,33)=3.10, \eta_p^2=.09, p=.08 \]. The three-way interaction indicated that Go trials elicited greater positivity in the waveform than No-go trials, but the difference between Go and No-go trials was greater during Block 4 than Block 3.

At the medial-lateral sites, there was a marginally significant three-way interaction between group, gonogo, and lexical repetition \[ F(2, 66)=3.63, \eta_p^2=.10, p<.05 \]. Post-hoc paired sample t-tests were performed to further explore the interaction. Since we were most interested in the repetition effect, we examined the Go trials only to determine how repetition modulated overt naming. For L2 learners, a marginally significant repetition effect was found in the Go waveforms such that repetitions from Block 2 elicited greater positivity than new items \[ t(1,17)=1.99, p=.07 \]. The mean amplitude of repetitions from Block 1 did not differ from new items \[ t(1,17)=1.22, p<1 \]. For monolinguals, differences in the mean amplitude were not found between new items and repetitions from Block 2 \[ t(1,17)=-.45, p<1 \]. However, repetitions from Block 1 elicited less positivity than new items \[ t(1,17)=-2.22, p<1 \]. At the lateral-lateral sites there was a significant interaction between group and lexical repetition. However, the two-way interaction was qualified by a significant four-way interaction between group, lexical repetition, gonogo and electrode. To further explore the four-way interaction, separate ANOVAs were conducted for each group over each electrode. The interaction likely in part reflecting that for L2 learners, greater positivity was observed in the P300 when repetitions from Block 1 and Block 2 were named than when new pictures were named. In contrast, greater positivity was elicited
when monolinguals named Block 2 repetitions and new items than when repetitions from Block 1 were named. Furthermore, the interaction likely reflected that difference in the amplitude between Go trials and No-go trials were most prominent at parietal electrodes for L2 learners, but were robust at frontal, temporal, and parietal electrodes for monolinguals.

Figure 5. Grand average ERP waveforms for L2 learners and monolinguals at electrode P3.

Taken together, the results revealed differences when monolingual and L2 learners completed the later Go/No-go blocks. In line with the predictions, differences were found when monolinguals and bilinguals named repetitions. We predicted that modulation of the Go/No-go response by repetition would be found for L2 learners, reflecting consequences of speaking the L2 for the L1. The results indicated that repetitions that were initially named in Spanish (L2) elicited significantly more positivity than new items, suggesting that learners suppressed the L1 translation equivalents of pictures that they had named in the L2. In contrast, for monolinguals, greater positivity was observed when new items were named than when repetitions from Block 1 were named. One explanation for the monolingual pattern is that it reflects recency effects. The repetitions from Block 1 appeared at the beginning of the task. Initial exposure during Block 1
might have allowed these repetitions to be consolidated in memory as a set of items that could be anticipated and responded to more efficiently later in the task. In other words, storing the old pictures from Block 1 as a set could facilitate processes that “mark” them as especially intrusive or less intrusive. Items marked as less intrusive (less recent) might require less control once the stimulus appears. Such an explanation has been given to explain performance on the “recent negatives task” (e.g., Borgess & Braver, 2010) and fits within the Dual Mechanisms of Control framework (e.g., Braver et al., 2009).

Interestingly, the standard comparison of Go waveforms to No-waveforms did not reveal patterns suggesting differential recruitment of control for learners and monolinguals. It might even be argued that, if anything, this comparison shows larger P300 effects for monolinguals than learners. To explore whether individual differences in cognitive control influenced the outcomes for learners and monolinguals, a post-hoc analysis was performed. In this post-hoc analysis, we used performance on the AX-CPT task to ask if there were differences in how proactive and reactive control was exploited by the learners and monolinguals to perform the Go/No-go task. The constant requirement to regulate the L1 in order to speak the L2 might create unique consequences for L2 learners’ cognitive control. If so, one might expect that the relationship between domain-general control and speech planning processes differs between learners and monolinguals.

Analyses of the ERPs with AX-CPT Scores as a covariate

In order to characterize the relationship between reliance on proactive and reactive components of control and Go/No-go naming, we carried out ANCOVA with a measure from the AX-CPT (e.g., Braver & Barch, 2002; Morales et al., 2015; Rosvold et al., 1956; Zhang, Kang, Wu, Ma, & Guo, 2015). We used the BSI (Behavioral Shift Index) measure from the AX-CPT to
quantify participants’ reliance on proactive and reactive control processes. A hypothesis that is gaining increasing support in the literature is that bilinguals modulate proactive and reactive control differently than monolinguals (e.g., Morales et al., 2015). The BSI is hypothesized to reflect an individual’s preference for reactive and proactive control (e.g., Zhang et al., 2015). It is calculated as a ratio of the difference in performance when the individual responds to AY (proactive) probe trials and BX (reactive) probe trials. A higher BSI score indicates that the individual prefers proactive control, whereas a lower score indicates that the individual prefers reactive control. BSI is usually measured as a composite of accuracy and RT ratios in the probe conditions. However, it has been established elsewhere that the BSI is typically highly correlated (e.g., Lamm, Pine & Fox, 2013). To simplify interpretation, we took the BSI for RTs only.

Previous results favor the hypothesis that bilinguals engage proactive and reactive control more flexibly than monolinguals, due to special expertise regulating the two languages (e.g., Morales et al., 2015; Zhang et al., 2015). The goal of this analysis however, was not to examine the BSI scores themselves, but the relationship between BSI and picture naming (i.e., a production task).

The repetition effect observed in the picture naming task alluded to the presence of differences in monolinguals’ and L2 learners’ reliance on control during speech planning. These effects were most prominent in the medial-lateral columns. Therefore, an ERP analysis was restricted to the P300 effect at the medial-lateral electrodes. The BSI was used as a covariate, in the ANCOVA analyses comparing the effects of block (Blocks 3 and Block 4), lexical repetition (new, repetition from Block 1, repetition from Block 2), electrode (Fronto-polar, Frontal, Central, Parietal, Occipital), and hemisphere (Left and Right). Two ANCOVAs were performed, comparing the relationship between BSI and the Go/No-go effects separately for each group. The data used for the ANCOVAs reported here reflect data from 14 learners and 14 monolinguals.
Data from four participants from each group whose accuracy averaged less than 40 percent in the AY and AX probe were eliminated. Although this inclusion criterion appears to be low, the AX-CPT task is cognitively demanding even for young adult participants. For the monolinguals, the two-way interaction between BSI and Go/No-go was marginally significant \([F(1, 12)=3.09, \eta_p^2=.21, p = .10]\). For the L2 learners, a significant two-way interaction was not found between BSI and Go/No-go naming \([F(1, 12)=0.01, \eta_p^2=.00, p < 1]\).

![Figure 6. Regression plot of the correlation between the BSI (AX-CPT) and the Go/No-go P300 effect (Go mean amplitude - No-go mean amplitude) detected at the medial-lateral columns.](image)

The results, although preliminary, suggest that the relationship between domain-general control and speech planning processes differed for monolinguals and L2 learners. Specifically, the results indicated that reliance on reactive and proactive control led to different outcomes on Go/No-go naming for learners and monolinguals. For monolinguals, greater reliance on proactive control (larger BSI) produced stronger inhibitory effects during Go naming. Greater reliance on reactive control (smaller BSI) produced weaker inhibitory effects during Go naming. For L2 learners, a statistically significant relationship between BSI and Go/No-go naming was not observed. However, it is clear that there were a few outliers in the sample. Because the
samples were small, we did not exclude the outliers. In addition, the outliers appear to fall out of the range because of the size of the Go/No-go response. It is not obvious why such large Go/No-go ERP responses were observed. Nevertheless, examination of the correlation for the learner group, ignoring the outliers, suggests an interesting pattern. Excluding the outliers, there appear to be opposite patterns for learners and monolinguals. Greater reliance on proactive control (larger BSI), by learners, appears to produce less inhibition during Go naming. Greater reliance on reactive control (smaller BSI), appears to produce more inhibition during Go naming. Though still very tentative, these preliminary results support the claim that experience regulating the L1 during production has consequences for learners’ cognitive control.

**Discussion**

The current study examined the relationship between language control processes during speech planning and domain-general cognitive control for L2 learners. We used a novel approach that embedded an executive control task directly within a speech production task. The logic of this approach extends from more recent studies of bilingual cognitive advantages, which focuses on the interaction between language processing and cognitive control in real-time (e.g., Blumenfeld & Marian, 2011; Wu & Thierry, 2013; Rodriguez-Fornells, et al., 2005). Like these studies, we attempted to catch inhibitory processes during language processing on the fly. Participants’ behavioral and ERP responses were recorded as the performed standard picture naming and a later Go/No-go picture naming task. The BSI measure from the AX-CPT task was used as an offline measure to provide additional information about the relationship between regulation of language during speech planning and domain general-cognitive control processes.

It was hypothesized that a differences in Go/No-go performance for monolinguals and would observed due to the presence of inhibitory processes when L2 learners spoke the L1 after
the L2. Another source of the differences was hypothesized to be long-lasting consequences of speaking an L2 (e.g., plasticity in cognitive control for L2 learners). The results provided evidence that the requirement to speak the L2 influenced subsequent Go/No-go performance. Learners were slower to name pictures than monolinguals during Block1, the initial block of L1 production. Since this block of naming occurred before L2 was spoken, the result suggests that learners modulate the L1 in anticipation of speaking the L2. In addition, learners were overall slower to name pictures in the Go/No-go block, a pattern suggesting global L1 regulation (e.g., Christoffels, Firk, & Schiller, 2007; Guo et al., 2011).

A correlational analysis, examining the relationship between AX-CPT performance and the Go/No-go picture naming task, revealed differences in the relationship between cognitive control and speech planning for learners and monolinguals. Learners appeared to recruit proactive and reactive cognitive control in a different manner than bilinguals for performing the very same task. This might reflect consequences of becoming a proficient user of two languages, which may be a unique form of cognitive training. Importantly, the result implies that consequences of bilingualism for domain-general cognitive control take root during the early stages of L2 development. Though the learners tested here represent just one of the many groups that make up the larger spectrum of multi-language users, testing intermediate-level learners demonstrated that it is possible to explore the consequences of bilingualism across a continuum of proficiency levels. The results from this study have implications for the debate on bilingual cognitive advantages as well. Particularly, it addresses is really at stake for researchers examining “bilingual advantages”. The evidence here suggests that the bilinguals did not outperform monolinguals in Go/No-go performance, but there were differences in how the groups performed the task. Importantly, the manipulations included within the study allowed us
to directly test the claim that differences were produced by virtue of bilingual language experience. This approach might be critical for advancing research on the topic of plasticity in cognition for bilinguals. Not only does the present study suggest this avenue will be fruitful for future research, but other studies using similar methods have demonstrate the utility of this approach. For example, Zhang et al. (2015) used a novel approach that attempted to directly link bilingual language experience with plasticity in cognitive control. The researchers trained a group of bilinguals on language switching and asked whether this group would experience enhancements to executive control. A control group of bilinguals, matched in cognitive and language skills served as the comparison group. Strong evidence for changes in the context of language switching training was observed. Thus, a major limitation in past research on “bilingual cognitive advantages” is that it did not attempt to seek the links between executive control and language processing directly.
Author Notes

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Chapter 6: General Discussion

The goal of the present dissertation was to investigate the mechanisms that enable L2 learners to plan speech in the L2 by examining the consequences of speaking the L2 for the L1. The predominant mechanism of control for L2 speech planning in learners might be inhibition, a form of control that is generally present during proficient bilingual speech planning. However, inhibiting the dominant language during L2 speech planning might be even more essential for speaking the L2 as a learner. The requirement to integrate two systems in one mind at early stages of bilingualism might produce extensive consequences for the L1 speech production system and for domain-general cognitive functions. In order to experimentally test these ideas, L2 learners’ speech planning processes were examined in an extended blocked picture naming paradigm.

6.1 Summary of findings.

The goal of Experiment 1 was to investigate the scope and the time course of the consequences of speaking the L2 on the L1 for L2 learners. A critical aim of this experiment was to demonstrate that the approach of focusing on the L1 as a window into L2 speech planning processes is effective. The logic of this approach was that modulations of the L1 after speaking the L2 are essentially reverberations of the processes that were effect while the L2 itself was spoken. The results of Experiment 1 provided evidence for modulation of the L1 after learners spoke the L2. Following the logic of previous blocked production paradigms, repetitions and new items were included to assess the presence of inhibitory mechanisms. The L2 learners demonstrated a mixture of inhibition and priming in the behavioral record, but generally priming in the ERP record. The locus of the effects appeared to occur at multiple levels within the
lexicon, even implicating global inhibition as a mechanism exploited by L2 learners for regulating the L1 during speech planning.

Experiment 2 aimed to further explore the scope and the consequences of speaking the L2 for the L1 speech planning processes. Specifically, this experiment investigated whether learners are affected by enduring consequences of becoming skilled at speaking an L2. This study was motivated by prior research demonstrating that proficient speakers experience enduring consequences of speaking an L2 for L1 production that distinguish them from monolinguals when they speak the L1 alone. To test this hypothesis, a second group of L2 Spanish learners were asked to perform the extended block picture naming task, but were instructed to speak the L1 only. Due to the limited experience learners have speaking the L2, this group was not expected to show enduring consequences of speaking an L2 when instructed to speak the L1 alone. In other words, the prediction was that L2 learners should resemble monolinguals when naming only the L1 during blocked picture naming. The results from this experiment confirmed the predictions. L2 learners who named in the L1 alone showed robust priming similar to the monolinguals who performed the same task. If the L2 learners had been engaging different processes, reflecting enduring consequences of speaking an L2, then they would not have shown large priming effects in the response latencies and ERPs. The results of Experiment 1 suggests that L2 learners do not parallel more proficient bilinguals in showing extended consequences of speaking an L2 that affect speech planned only in the L1.

The aim of Experiment 3 was to directly investigate the relationship between cognitive control and speech planning processes. The hypothesis tested in Experiment 3 was that cognitive control processes would be recruited by L2 learners planning speech in L1 after speaking the L2. Thus, there would be an impact of prior recruitment of cognitive control during speech planning.
for learners’ subsequent performance in a Go/No-go task. In order to investigate whether learners experience cognitive consequences of experience inhibiting the L1 during speech planning, L2 learners were compared to a group of monolinguals who performed the same task, but entirely in the L1. A key prediction was that the requirement to speak the L2 during picture naming would affect how L2 learners performed the Go/No-go task. Specifically, it was predicted that if there were inhibition of the L1 during L2 production, there would be reduced facilitation when repetitions were named on Go trials. The results revealed a repetition effect on Go trials when L2 learners named pictures that was consistent with inhibition. In addition, the Go/No-go naming patterns differed between L2 learners and monolinguals. Furthermore, the analysis of individual differences in inhibitory control, as indexed by a measure from the AX-CPT, indicated differences in the relationship existed between inhibitory control and Go/No-go naming for monolinguals than L2 learners. Although the results are somewhat preliminary, as the sample size of each group was small, the overall patterns suggest that monolinguals and L2 learners were differentially impacted by cognitive control resources when they performed Go/No-go picture naming.

6.2 Conclusions.

The assumption held by most of the current models of bilingual speech planning is that L2 learners rely on inhibition even more than proficient bilinguals to enable production in the L2. The implication of the predictions of models of bilingual speech planning is that there should be very extensive consequences for the L1 when L2 learners plan speech in the L2. Evidence for consequences of emerging bilingualism was found when L2 learners plan speech, but the consequences were not consistent with the notion that learners engage inhibition more strongly than proficient bilinguals. When L2 learners spoke the L1 after the L2, there was evidence for
global and local inhibitory effects on subsequent production in the L1. However, inhibition was observed along with priming, suggesting that inhibition might not be the only mechanism present during L2 learners’ speech planning. Critically, only learners who spoke the L1 after the L2 demonstrated this effect. There was no evidence for global inhibition when learners spoke the L1 after the L2. This suggests that, for L2 learners, inhibition occurs in the immediate requirement to speak the L2. Unlike proficient bilinguals, the L1 does not appear to be sensitive to the L2 when learners speak the L1 only.

A dissociation was observed between the behavioral measures and ERPs, with ERPs revealing stronger evidence for priming than inhibition. Because inhibitory effects were found at the behavioral level, it cannot be argued that the task was insensitive to the presence of inhibitory mechanisms during speech planning. Instead, the dissociation may reflect the difference in weighting of early and late processes of speech planning for behavioral and ERP measures. The N200 component revealed significantly more positivity when repetitions were named in the L1 after speaking the L2. This result is surprising given the high volume of papers on the topic of bilingual language control during speech planning that have implicated the N200 as a marker of inhibition (e.g., Misra et al., 2012; but see Verhoef et al., 2009). The pattern of facilitation observed for the L2 learners in the N200 might reflect early visual processes that precede detection of language conflict and recruitment of inhibition. However, inhibitory effects were not observed in later components that were inspected in the ERP waveforms either. One explanation for this is that when learners plan speech, ERPs are very sensitive to facilitation, cancelling any of the inhibitory effects out. At the point of speech must be overtly produced, however, facilitation and inhibition may converge. Generally, inhibition may figure more prominently in behavioral measures since ultimately output must be selected for articulation. A distinction,
similar to the one made here for ERPs and behavioral measures has been proposed in theories of how comprehension differs from production. The similarity, in principle, is that processes that are initiated in a bottom-up fashion are more likely to be open to mutual resonance (facilitation) in codes/sources of linguistic information, but top-down initiated processes might be more influenced by competition and interference. This logic can extend to ERPs, if one understands the basic requirement in the earliest moments of naming a picture to be implemented through passive, automatic processing routines. For the less proficient L2 learners, selecting between languages might be an effortful process that is not fully implemented until later stages of planning.

Another aspect of the inhibitory account, the time course of inhibition, was examined in the current dissertation study. Behavioral measures revealed consequences of speaking the L2 on the L1 that were long-lasting in time course. An extended blocked picture naming paradigm, including six blocks of L1 production following production in the L2, was used to examine precisely how long the consequences of speaking the L2 manifested over time. A local inhibitory effect, reflecting a reduction of lexical repetition priming, was observed when L2 learners spoke the L1 after the L2. In addition, a category-specific effect, reflecting a reduction in category priming, was observed for the same group of L2 learners. Critically, the reduction in lexical priming was observed for four out of the six L1 blocks that followed L2 production. In addition, there was no evidence that category priming was recovered in the time span allotted by the task. These findings parallel patterns that have been observed when proficient bilinguals speak the L1 after the L2, suggesting the presence of long-lasting inhibitory mechanisms. Like previous studies (e.g., Branzi et al., 2014; Van Assche et al., 2013), the present study found evidence mechanisms that vary in scope converge to influence speech planning simultaneously. The novel
insight gained in this study is that these mechanisms vary with respect to time course, overlapping at some points, but also having distinct trajectories. This observation might prove especially important for modifying existing or developing new models of bilingual speech planning.

Experiment 2 compared monolinguals and L2 learners performing the extended block picture naming task entirely in the L1. The question asked in Experiment 2 was whether L2 learners demonstrate evidence of sensitivity to increasing proficiency in the L2 that is reflected in changes to L1 production. Indeed, investigations of L1 production in proficient bilinguals suggests that bilingualism heightens the demands on production even when the L1 is the only language spoken (e.g., Parker-Jones et al., 2012). Behavioral measures and ERPs were collected during L1 only production to examine the possibility that such sensitivity exists for L2 learners. Unlike Parker Jones et al. (2012), the dissertation results did not provide evidence for enduring consequences of speaking the L2 on the L1. L2 learners who spoke the L1 alone named pictures in the extended blocked naming task similarly to monolinguals naming in the L1. L2 learners and monolinguals experienced similar levels of priming when lexical repetitions were named. If L2 learners were sensitive to the enduring consequences of speaking an L2, then one would expect that they would more closely resemble L2 learners who actively spoke the L2. Large amounts of facilitation from repetitions was present when L2 learners named in the L1 only, but in contrast there was virtually no evidence for facilitation when L2 learners actively named pictures in the L2. Taken together, the current results suggests that at this relatively early stage of bilingualism, learners do not have sufficient exposure to the L2 to distinguish them from monolinguals in L1 only production.
At present, the results would appear to firmly argue that there are no enduring consequences of speaking an L2 on the L1. However, one possibility is that immersed L2 learners would show consequences of emerging proficiency in an L2 when speaking the L1 alone. Previous research has shown dramatic effects of immersion on L2 learners’ native language production (e.g., Linck et al., 2009). One explanation for this is that L2 learners are speaking the L2 more frequently, which may induce retrieval-induced forgetting like phenomena for the L1 (e.g., Levy, McVeigh, Marful, & Anderson, 2007). The basic idea of retrieval-induced forgetting is that retrieving a memory entails suppression of potentially interfering memories. The analogy for immersion is that increased use of the L2 for speech production entails suppression of the dominant L1. Linck et al.’s study demonstrated evidence supporting this idea, since L2 immersed learners produced less words in their dominant language on a verbal fluency task than non-immersed L2 learners. One aspect of Linck et al.’s study that remains unclear is whether the L1 was affected globally, even when they were not required to retrieve words in the L2 during the task. A prediction would be that immersed learners show large difference when compared to monolinguals speaking the L1 alone. However, it appears necessary to consider whether the design of the extended blocked picture naming would enable immersed learners to recover the L1. Potentially, this avenue of research can provide critical information about how immersion factors differ from proficiency factors. Not only does it seem relevant to compare immersed learners naming in the L1 alone to monolinguals, but it also would be informative for models of bilingual speech planning to compare immersed learners to classroom learners naming in the L1 alone. Research suggests (Jacobs, Fricke, & Kroll, in press) that proficiency and immersion experience have distinct influences on speech planning, indicating that it may be possible to adjudicate between the alternatives in future research.
Experiments 1 and 2 tested the hypothesis that inhibition is when L2 learners plan speech. This dissertation demonstrated evidence of inhibition when L2 learners spoke the L1 after the L2. To the extent that inhibition was observed at all, this finding is partially consistent with the Inhibitory Control model (Green, 1998). It is also partially inconsistent with the model because very large inhibitory effects, larger in magnitude than what has been previously reported when proficient bilinguals plan speech, were not observed. This result was surprising, not only given the predictions of Green’s model, but also empirical results from studies that have investigated the relationship proficiency and reliance on inhibition during speech planning. For example, Meuter and Allport’s (1990) seminal language switching study demonstrated that there was a relationship between proficiency and the degree of inhibition engaged for speaking the L2. The results of this study indicated that bilinguals who were less skilled in speaking the L2 demonstrated larger switch costs asymmetries than more proficient bilinguals. Overall, the results of the dissertation did not reveal inhibitory effects that were as robust as expected on the basis of previous findings. Critically, the L2 learners who participated in the dissertation study were much less experienced speaking the L2 than the learners tested in previous studies. One implication of the dissertation findings is that learners might not be as skilled as proficient bilinguals at using inhibition. It is obvious that L2 learners do not speak the L2 as frequently as they speak the L1 on a daily basis. It is also a well-known fact that L1 entrenchment ensues quite early in monolingual language development (e.g., De Houwer, A., 2005). Perhaps the skill associated with speaking the L1 and the limited time spent practicing L2 speech limit the strength of inhibition at early stages of bilingualism. In other words, the automaticity and skill associated with speaking the L1 may prevent it from experiencing consequences of speaking the L2 until substantial experience speaking the L2 has been gained. This might explain why in
immersion contexts evidence for L1 instability has been found. The “brakes are put on the L1” so to speak, allowing the weaker language to gain some automaticity. In the absence of communicative pressures or frequent routines that force them to switch languages, it is not surprising that L2 learners’ L1 dominance is allowed to go unperturbed and overshadow the effects of the emerging L2 system.

According to the Adaptive Control Hypothesis (Green & Abutalebi, 2013), bilingualism alters how linguistic and cognitive networks are tuned. A main assumption in this hypothesis is that various aspects of the bilingual’s language experience (i.e., the context of language use, the sociolinguistic habits of interlocutors, preferences of the speaker themselves) will tune the networks to optimally adapt to the input of the environment. Many adult second language learners live in L1 dominant environments, where use of the L2 is limited to occasional formal interactions. Therefore, one would not expect that L2 learners can tune themselves to the input of the environment, developing executive functions for the purpose of alternating between languages or remaining in single language during production. Instead, given the infrequency of multilingual language use, it might take a considerable length of time for L2 learners to adapt to this form of language use and show evidence of systematic changes to executive functions.

Experiment 3 compared L2 learners’ and monolinguals’ performance on a domain-general executive control task using ERPs and behavioral measures. If one assumes that cognition is not impacted by bilingual language experience at early stages of L2 development, the results of Experiment 3 would be rather surprising. Experiment 3 demonstrated that L2 learners differed from monolinguals in reliance on cognitive control. The results reported in this dissertation indicated that speaking the L2 had later consequences for how performed Go/No-go picture naming. Specifically, the pattern of repetition priming observed when learners performed
Go/No-go suggested that they were engaging control during speech planning differently than monolinguals. In addition, correlation analyses revealed differences in the relationship between cognitive control and speech planning for learners and monolinguals.

The results of the dissertation study highlight that bilingualism is a continuum, and binary distinctions between less and more proficient bilinguals might not be able to capture the range of consequences that occur when individuals become proficient speakers of an L2. Considering the extensive variation in bilingual language usage and diversity in bilinguals themselves, makes the prediction for multiple mechanisms of bilingual language control extremely intuitive. Importantly, in the recent decade there has been an upswing in research investigating processes of speech planning for late, but proficient bilinguals, complementing the research on highly proficient balanced bilinguals (e.g., Guo et al., 2011; Misra et al., 2012; Van Assche et al., 2013; Rossi et al., in prep). The current dissertation adds an additional perspective to topics within bilingual speech planning by focusing on production in the early stages of bilingualism. This research is important for bringing the interplay between speaker and contextual factors to the forefront. Different types of bilinguals experience different levels of interactions between the two languages during speech planning (e.g., Kroll et al., 2006). Different types of linguistic contexts will prompt different forms of control (e.g., Abutalebi & Green, 2013). Hence, this suggests that addressing fundamental questions such as “How do behavioral measures relate to electrophysiological and imaging measures of spoken production?”, “How do the cognitive stages of speech planning interact with phonetic/articulatory stages?”, and “What is the nature of the relationship between bilingual experience and cognitive plasticity?” will involve a great deal of complexity. However, when pulled together, research that targets different bilingual
populations might ultimately prove to be the most effective strategy for addressing these topics in years to come.
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## APPENDIX A
### PICTURE STIMULI USED IN EXPERIMENTS 1 AND 2

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## APPENDIX B

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APPENDIX C
GRAND AVERAGE ERPS FOR EXPERIMENTS 1 AND 2

Block 1 vs. Block 2. *Learners naming L1 after L2* Grand Average ERPs for Block 1 and Block 2. Negative is plotted up.
New vs. New from repeated categories. *Learners naming L1 after L2* Grand mean waveforms for the new and the new from Block 1 and Block 2. Negative is plotted up.
New vs Lexical repetitions. *Learners naming L1 after L2.* Grand mean waveforms for the new and the lexical repetitions from Block 1 and Block 2. Negative is plotted up.
Block 1 vs. Block 2. *Learners naming L1 only.* Grand Average ERPs for Block 1 and Block 2. Negative is plotted up.
Block 1 vs. Later Blocks. *Learners naming L1 only.* Grand Average ERPs for Block 1, Blocks 3 and 4 (New), Blocks 5 and 6 (New), Blocks 7 and 8 (New). Negative is plotted up.
New vs. New from repeated categories. *Learners naming L1 only.* Grand mean waveforms for the new and the new from Block 1 and Block 2. Negative is plotted up.
New vs Lexical repetitions. *Learners naming L1 only.* Grand mean waveforms for the new and the lexical repetitions from Block 1 and Block 2. Negative is plotted up.
Block 1 vs. Block 2. *Monolinguals naming L1 only*. Grand Average ERPs for Block 1 and Block 2. Negative is plotted up.
Block 1 vs. Later Blocks. *Monolinguals naming L1 only*. Grand Average ERPs for Block 1, Blocks 3 and 4 (New), Blocks 5 and 6 (New), Blocks 7 and 8 (New).
Negative is plotted up. New vs. New from repeated categories. *Learners naming LI only.* Grand mean waveforms for the new and the new from Block 1 and Block 2. Negative is plotted up.
New vs Lexical repetitions. *Learners naming L1 only.* Grand mean waveforms for the new and the lexical repetitions from Block 1 and Block 2. Negative is plotted up.
Vita
Rhonda McClain

Education
2011 Master of Science in Psychology, The Pennsylvania State University
2007 Bachelor of Science in Psychology, University of Pittsburgh

Research Support
2013-2015 National Institute of Health Predoctoral Training Grant (with Judith F. Kroll and Eleonora Rossi). NICHD F31HD075545-01: A neurocognitive investigation of the scope and time course of inhibition in bilingual speech ($87,537)
2012-2014 National Science Foundation Dissertation Research Grant (with Judith F. Kroll). BCS-1226471: Using ERPs to track the scope of inhibition in bilingual speech ($53,442)
2010 Partnership in Research and Education (PIRE) Research Fellowship, Pennsylvania State University ($2000)
2010 Herschel W. Leibowitz Graduate Scholarship, Department of Psychology, Pennsylvania State University ($2000)
2009-2012 Ford Foundation Predoctoral Fellowship ($54,000)

Selected Publications

Selected Presentations and Invited Colloquia
McClain, R., Rossi, E., & Kroll, J.F. (2013, October). Using ERPs to investigate the scope and time course of inhibitory control in bilingual production. Poster presented at the International Conference on Multilingualism, Montreal, Quebec, Canada.

Selected Awards/Honors
2008-2009 Bunton-Waller Award, College of the Liberal Arts Research and Graduate Studies Office, The Pennsylvania State University
2008-2009 Center for Language Science Award, The Pennsylvania State University