The Pennsylvania State University

The Graduate School

Department of Psychology

THE ROLE OF INHIBITION IN THE CONTROL OF BILINGUAL SPEECH PRODUCTION

A Dissertation in

Psychology

by

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

December 2008

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ABSTRACT

Recent psycholinguistic research suggests that activation spreads in parallel to both of a bilingual's languages when speaking. Some models of bilingual word production (e.g., Green, 1998) assume that activated lexical alternatives in both languages compete for selection and that this competition is resolved by an inhibitory control mechanism. Evidence for inhibition during speech planning has been accumulating in recent behavioral and neurophysiological studies of bilingual speech production. Recently, Levy, McVeigh, Marful, and Anderson (2007) reported that repeated picture naming in the second language (L2) induced inhibition of the picture's name in the first or dominant language (L1). This inhibition was argued to operate at the level of the phonology. The current study was designed to directly test this claim using an online measure of inhibition. In a series of four experiments, L2 learners and highly proficient bilinguals named pictures in English and Spanish. The English names of these pictures were later presented as items in a lexical decision task to examine whether naming pictures in Spanish had consequences for subsequent access to the English picture names. All four experiments failed to replicate the inhibitory effects reported by Levy et al. If anything, naming pictures in Spanish facilitated rather than inhibited retrieval of the corresponding English picture name. The results of this study highlight the need for a clearer elucidation of the nature of inhibition in bilingual speech production. The implications for the role of inhibitory control in models of bilingual speech production are discussed.

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ACKNOWLEDGEMENTS

This dissertation research would not have been possible without the financial support of the Pennsylvania State University College of Liberal Arts Dissertation Support Grant, the National Science Foundation Grant BCS-0418071 to Judy Kroll, and the National Institutes of Health Grant R56-HD053146 to Judy Kroll. My sincerest thanks also go to the research assistants in the Language and Cognition Lab who worked diligently in the lab to create the materials, administer the experiments, and score and enter the data. Specifically, I would like to thank Christina Baer, Nurcan Cile, Oscar Lee, and John McCormick. Thanks also go to our lab coordinator, Mark Minnick, for his reliability and willingness to help when needed.

I am thankful to have had such a wonderfully supportive group of colleagues over the past five years. First and foremost, I want to thank my lab mates, who have always been there to help me overcome any obstacle. To Noriko Hoshino, Susan Bobb, Kate Cheng, Tyler Phelps, and April Jacobs, I send my deepest appreciation for creating such a friendly and welcoming environment in the lab. Many thanks also go to former lab members Ana Schwartz, Gretchen Sunderman, Natasha Tokowicz, and Maya Misra, for being encouraging and supportive colleagues during these first years in my career. My development during graduate school was also largely shaped by the intellectual community at Penn State, where I was lucky enough to have two “homes”: the Cognitive Psychology area and the Center for Language Science. I would not be the researcher I am today if not for the constructive feedback, encouragement, and support I received from members of both groups. I am so grateful to have had the opportunity to interact with all of you. Thanks also go to my dissertation committee members – Rich Carlson, Bob Schrauf, Dan Weiss, Michael Wenger, and Nuria Sagarra. Thank you all for the time, energy and effort you put into providing me with your guidance and support.

I want to thank in particular my advisor and mentor Judy Kroll. I continue to be amazed by the energy, enthusiasm and dedication you put into your work. Your guidance and support has helped me to learn and grow a lot over the past five years. I certainly would not be where I am today without your encouragement. I look forward to having students of my own some day, and I hope that I can provide them with the expert guidance and wisdom that you have shared with me. Thank you, Judy!

Finally, I could not imagine arriving at this point in my life and career without all the love and support of my wife, Jessica. You helped me in so many ways during our five years at Penn State. During the really stressful moments in grad school, you always knew what I needed. Whether it was putting that little extra bit of loving pressure on me to get things done, or kindly reminding me that taking a small break from my work to have some fun was both necessary and productive, you helped me to remain focused on my goals of being a good scientist and, more importantly, a great person. You inspire me and energize me, and I am so grateful to have you in my life.

Chapter 1

Introduction

The fact that bilinguals are able to functionally control the language they are speaking is a feat of cognition. There is a growing body of evidence suggesting that activation spreads in parallel to representations in both languages during comprehension and production, and that even highly proficient bilinguals cannot effectively “turn off” the language not in use (e.g., Bijeljac-Babic, Biardeau, & Grainger, 1997; Colomé, 2001; Hermans, Bongaerts, De Bot, & Schreuder, 1998; Jared & Kroll, 2001; Van Hell & Dijkstra, 2002; for a review, see Kroll, Sumutka, & Schwartz, 2005). This suggests that the bilingual is equipped with the cognitive mechanisms necessary to control the two languages. Yet there is still debate as to whether activated items in the two languages compete for selection and, if they do, by what mechanism and at what level this competition is resolved (e.g., Bloem, van den Boogaard, & La Heij, 2004; Costa, Santesteban & Ivanova, 2006; Finkbeiner, Gollan & Caramazza, 2006; Kroll, Bobb, Misra & Guo, 2008). One plausible mechanism for the resolution of this competition is inhibition (e.g., Green, 1998; Meuter & Allport, 1999; Kroll et al., 2008; Linck, Kroll, & Sunderman, in preparation).

The aim of this study was to investigate whether L2 learners and proficient bilinguals inhibit the non-target language during speech production using a novel methodological approach. We first begin with a review of the evidence suggesting that activation spreads in parallel to representations in both of a bilingual’s two languages – in some circumstances through to the level of the phonology – focusing primarily on the literature on speech production. Various bilingual speech production models are then described, noting important differences in the mechanisms they claim support language selection. We then focus the discussion on the role of inhibition in bilingual speech production. Recent developments in research on bilingual language production and the neurocognition of bilingual language control are converging on the idea that inhibitory mechanisms support language selection, and that the underlying neural mechanics are similar to those implicated in the control of memory more generally. Finally, predictions are made regarding inhibition during speech production and its consequences for subsequent language use.

A Model of Bilingual Speech Production

Figure 1-1 (adapted from Hermans, 2000; Poulisse & Bongaerts, 1994) presents a representative model of bilingual speech production. During speech planning, activation within the bilingual lexico-semantic system spreads through three levels of representation. First, the intention to speak activates nodes at the conceptual level, which represent the conceptual features of the object. Note that a picture provides the initiating event in the example model provided in Figure 1-1, but the planning process could also be initiated by other events such as a word for translation or an abstract thought. The conceptual nodes then spread activation to lemmas (or word representations) in both languages that are associated with the activated concept. In this example, when a Dutch-English bilingual prepares to name the picture of a bike, activation spreads from the conceptual level down to the lemmas of both translation equivalents (*bike* and the Dutch word *fiets*) as well as other associated words (e.g., motorcycle). Note that the lemma level nodes of the translation equivalents of the picture's name receive the most activation, whereas the names of associated but distinct concepts (e.g., motorcycle) receive less activation due to the incomplete activation of those lemmas' conceptual level nodes. Finally, the lemma level nodes spread activation to their associated phonological representations, thereby allowing articulation of the spoken word to occur.

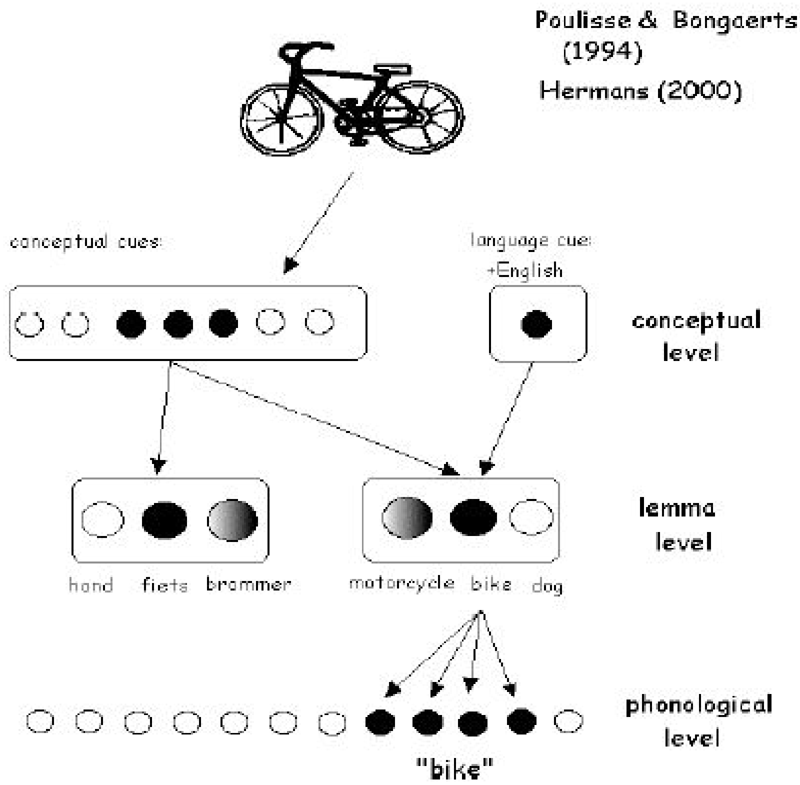

Figure 1-1: A model of bilingual speech production, adapted from Poulisse & Bongaerts (1994) and Hermans (2000).

Different assumptions have been made regarding the flow of activation. According to a *language specific activation model*, the intention to speak restricts the flow of activation to the target language only. By this view, the bilingual mind is seen to contain two distinct monolingual language systems that function independently as if the speaker were monolingual. In contrast, *language non-specific activation models* assume that activation cascades through both the target and non-target languages to varying degrees. That is, the intention to speak does not suffice to limit activation to the target language. As the following review will show, the evidence suggests that parallel activation spreads to both languages in some cases all the way through to the level of the phonology, even with highly proficient bilinguals who demonstrate an exquisite level of control during production.

Parallel Activation at the Semantic and Lexical Levels

In a study involving monolinguals and bilinguals, Gollan, Montoya, Fennema-Notestine and Morris (2005) presented picture classification and picture naming tasks to the two language groups. Although the bilinguals were reliably slower to name pictures relative to the monolinguals, they were equally as fast when performing the picture classification task, suggesting that conceptual access was not different across the two groups. However, for the bilinguals, pictures that most bilinguals could name in both languages (i.e., highly translatable pictures) were named reliably faster than pictures that most bilinguals only knew in one language. The authors concluded that, when both translations were known, parallel activation spread to both translations and this activation of the non-target language facilitated retrieval in the target language.

Other researchers have also reported evidence of cross-language facilitation. Using the picture-word interference paradigm, Hermans (2004) found that L2 picture naming was facilitated when the L1 word for the picture was presented simultaneously. That is, despite the knowledge that naming was to occur only in the L2, the presence of the picture's L1 name influenced performance. Miller and Kroll (2002) found both facilitation and interference in a translation task, but critically it depended both on the nature of the target—distractor relationship and on the language of the distractors. When the distractor was in the language of production (Experiment 1), there were reliable effects of semantic interference and form facilitation. Yet if the distractor was presented in the input language (i.e., in the same language as the to-be-translated word, as in Experiment 2), these effects essentially disappeared.

It is important to note that the stimuli in a translation task (i.e., words) such as that reported by Miller and Kroll (2002) inherently provide cues regarding language membership through their orthographic representations, whereas more conceptually based tasks like picture naming do not provide such information. Kroll, Bobb and Wodniecka (2006) have argued that language selection (including the influences of parallel activation) is constrained by a variety of factors, including the demands of the production task. This is evident in Miller and Kroll's findings that the language of the distractor words moderated the influence of parallel activation on translation performance.

Others have found that cross-language activation can also interfere with language production. Lee and Williams (2001) found that producing a word in one language (e.g., rain) had a deleterious effect on the subsequent naming of related concepts in *either* language (e.g., snow, or “nieve”, in Spanish). Furthermore, if the participant had switched into the L2 on trial *t-1* and then back into the L1 on trial *t*, the between-language interference effect was eliminated. The authors interpreted the elimination of the interference effect after switching languages as evidence that the interference was due to competition at the lexical level, which was attenuated when by inhibition of the non-target language (e.g., Green, 1998; Meuter & Allport, 1999). This proposal that inhibition guides language selection will be considered in more detail below.

The parallel activation of bilingual lexical knowledge seems to extend beyond simple picture naming or word translation tasks to more naturalistic contexts. In a review of code-switching data, De Bot and Schreuder (1993) reported many examples of naturally occurring language errors in which the syntactic structure of a phrase was built from one language, with lexical entries from the other language being inserted in that phrase. Thus, the parallel activation of lexical items in the non-target language can in fact permeate to the level of syntactically rich productions, despite the potentially useful, language-specific syntactic information available.

Parallel Activation at the Phonological Level

Given the evidence of parallel activation at the lexical level, it then becomes important to question whether this activation spreads to the phonological representations.

One critical piece of evidence comes from studies documenting cognate facilitation. Cognates are translations that share highly similar phonology and orthography. Costa, Caramazza and Sebastián-Gallés (2000) compared naming latencies of cognate pictures (e.g., *guitar—guitarra*) and non-cognate pictures (e.g., *table—mesa*) to ask whether the non-target translation's phonological representation is activated when naming the target translation. Cognate pictures were named significantly faster than non-cognate pictures, suggesting that activation spread in parallel to the non-target translation's phonological representation. Recently, Hoshino and Kroll (2008) had Spanish-English bilinguals and Japanese-English bilinguals name cognate and non-cognate pictures in their L2 in order to examine whether parallel activation of the phonology is restricted to the case where the two languages share the same script. In fact, they found significant cognate facilitation with both bilingual groups, suggesting that differences in script do not constrain cross-language activation of the phonology.

In a study involving highly proficient Catalan-Spanish bilinguals, Colomé (2001) presented pictures to participants and asked them to judge whether a cued phoneme was present in the L1 name of the picture. The stimuli were manipulated such that the cued phoneme was present in 1) the Catalan word, 2) the Spanish translation, or 3) neither word. If activation at the phonological level only occurs for the target word (in this case, the Catalan name of the picture), then we would predict that the participants would be equally able to respond "no" to the Spanish translation condition and neither word condition. However, if instead activation spreads in parallel across both languages through to the phonological level, then the participants should take significantly longer to respond "no" the Spanish translation condition due to the presence of the cued phoneme in the non-target translation. The results confirmed the second prediction: participants took reliably longer to reject phonemes that were present in the Spanish translation stimuli, suggesting that activation at the phonological level also occurred in parallel, even with highly proficient bilinguals.

Similarly, Hermans et al. (1998) found interference effects from the non-target language phonology in a variant of the picture-word interference task. In this study, pictures were presented with auditory distractors, some of which were related in phonological form to the non-target translation of the picture's name. The critical finding for this discussion is that when these distractors were presented prior to or at the onset of the picture, the highly proficient bilinguals took reliably longer to name the picture in the target language than when the distractors were unrelated in phonological form to the picture's name. In a series of form-preparation experiments, Roelofs (2003) trained bilinguals on various word pairs (e.g., table—flower), and then later presented the first word (*table*) as a prompt to produce the second, target word (*flower*) in the pair. Participants produced the target words more quickly with sets in which the phonological onset of the target words were identical (e.g., the /f/ sound in *flower*, *feet* and *farmer*) compared to sets in which the onsets were non-identical (e.g., *flower*, *street* and *tomato*), since the former sets allowed them to essentially begin preparing the phonological productions even before the target word was selected. Importantly, this preparation effect was found even when the set of target words was a mixture of words from both languages, providing evidence that the preparatory activation of the initial phonological representations could spread across both languages. In sum, there is converging evidence from a variety of tasks suggesting that activation spreads in parallel across a bilingual's two languages through to the level of the phonology.

Models of Bilingual Language Selection

If representations in both languages are active and available to some degree during the speech planning process, two important questions emerge. First, how is the correct output selected? Second, at what locus (or loci) in the bilingual speech production system does selection occur? Bilingual speech production models fall into one of two classes based on their mechanism for selection: *competition-for-selection models,* which assume that language non-specific activation creates cross-language competition among candidate representations that must be resolved before production can proceed, and *non-competition models,* which assume that activation spreads to representations in both languages but that some control mechanism prevents these representations from competing during the selection process. Example models from these two classes are reviewed below.

The Competition-for-Selection Model

The central premise of this model is that the intention to speak spreads activation in a top-down manner to lexical candidates in both languages, and that this parallel activation results in cross-language competition that must be resolved for successful production to occur. Evidence in support of the competition-for-selection model has come from multiple lines of investigation (for a recent review, see Kroll et al., 2008). Let us consider the evidence coming from research using a variant of the Stroop task known as the picture-word interference paradigm. In a typical experiment using this paradigm, a picture is presented alongside a distractor word, and the participant is instructed to name the picture while ignoring the distractor. On some trials, the distractor word is semantically related to the name of the picture (e.g., *motorcycle*, for the picture of a *bike*); on other trials, the distractor word is phonologically or orthographically related to the picture (e.g., *bite*). The standard finding in this paradigm is that semantically related distractor words interfere with picture naming performance, leading to slower naming latencies, whereas phonologically or orthographically related distractor words facilitate picture naming, leading to faster naming latencies (e.g., La Heij, Van der Heijden, & Schreuder, 1985; Lupker, 1979, 1982). Crucial to the competition-for-selection model is the fact that semantic interference as well as phonological and orthographic facilitation are even found when the critical distractor word is presented in the non-target language (e.g., Costa, Miozzo, & Caramazza, 1999; Hermans et al., 1998), suggesting that activation not only spreads to both languages in parallel but also affects selection of the target word.

How does the competition-for-selection model account for such cross-language effects? The lemma level representations of semantically related distractors (*motorcycle*, in this example) receive activation from the distractor word input, but also from the conceptual representation of the picture of the bike (due to the overlap of a subset of conceptual features). This increases the activation level of the distractor, creating competition between *bike* and *motorcycle* at the lemma level (and perhaps also at the phonological level, depending on various factors as mentioned below). This competition interferes with the selection of the output word since additional time is required to resolve the competition, leading to detectable slowing in naming latencies. In contrast, when viewing phonologically and orthographically related distractors, facilitation is driven by the increased activation of phonological representations. Specifically, the lemma for *bike* spreads activation to its corresponding phonological representations (i.e., [b] [aɪ] and [k]); in addition, the related distractor also activates some of these phonological representations (i.e., *bite* activates [t] but also [b] and [aɪ]), and this overlap in phonological activation thus facilitates the production of the target phonological representations. To summarize, a key claim of this model is that activation spreads in parallel to representations in both languages which then compete with one another for selection. Although some factors seem to influence the extent to which parallel activation spreads down to the phonological level (e.g., semantic context; Schwartz & Kroll, 2006; Van Hell & De Groot, 2008), the fact that cross-language phonological effects have been found suggests that, at the very least, the system is flexible enough to allow language selection to occur at various points during the flow of activation (Kroll et al., 2006).

Non-competition Models

The Language-Specific Selection Mechanism Model

Although the above data support the claims of cross-language competition during selection, Costa and colleagues (Costa & Santesteban, 2004; Costa et al., 2006) have argued that for highly proficient bilinguals, activation spreads in parallel but representations in the non-target language do not compete for selection. Instead, any bilingual who has acquired a high level of proficiency in any pair of languages makes use of an attentional control mechanism that restricts the possible pool of candidates for selection to representations in the target language only. According to this model, highly proficient bilinguals show symmetrical switch costs (see discussion below for more details) not because cross-language competition affects both languages to a similar degree (e.g., Green, 1998) but instead because the language-specific selection mechanism prevents cross-language competition from occurring in the first place. Note that symmetrical switch costs in highly proficient bilinguals are compatible with both models but are explained by different mechanisms.

Empirical support for this model has come from the picture-word interference paradigm reviewed above. Recall that semantically related distractor words have been found to slow picture naming, even when the distractor word is presented in the non-target language. Since translation equivalents (e.g., *dog* and the Spanish equivalent *perro*) share a common semantic representation, they are more similar than within-language semantically related words (e.g., *dog* and *cat*). Thus, if representations in both languages compete for selection, one might expect the presentation of the translation equivalent as the distractor word to slow naming even further, which Finkbeiner, Gollan et al. (2006) termed the "hard problem" of lexical selection. Contrary to this prediction, translation equivalent distractor words have been found to facilitate picture naming relative to unrelated control words (e.g., Costa & Caramazza, 1999; Costa et al., 1999), providing evidence that activation of the non-target translation equivalent did not impact selection.

But, Hermans (2004) has argued that such evidence cannot adjudicate between competition and non-competition models. Specifically, his argument focuses on the finding that translation facilitation effects are very short-lived, disappearing at longer SOAs (e.g., Costa et al.). According to non-competition models, when the translation distractor is presented at longer SOAs, the non-target language activation occurs too late to affect production and thus facilitation diminishes with increasing SOAs. According to competition-for-selection models, cross-language competition increases as the SOA increases, and this competition is responsible for the disappearance of the facilitation effect. Thus, translation facilitation in and of itself cannot be taken as evidence against either class of models.

The evidence from language switching tasks is more mixed. Support for non-competition models comes from experiments in which highly proficient bilinguals performed a language switching task with their strong L1 and a weaker L3 (Costa & Santesteban, 2004, Experiment 4) or their relatively strong L2 and a weaker L3 (Costa et al., 2006, Experiment 2). In both experiments, symmetrical switch costs were found despite the large difference in proficiency levels of the two tested languages. These results confirm the predictions of the language-specific selection mechanism model and are incompatible with the competition-for-selection model. However, Costa et al. failed to replicate this result in their Experiment 3. When proficient bilinguals performed the task in the much weaker L3 and L4, they found asymmetrical switch costs. This finding is in direct opposition to the claims of the language-specific selection mechanism model, highlighting limitations of such an account of bilingual language production.

The Language-Specific Threshold Model

Others have proposed a language-specific threshold model as a solution to the "hard problem" of lexical selection (e.g., Finkbeiner, Gollan et al., 2006; Finkbeiner, Almeida, Janssen, & Caramazza, 2006). According to this account, the intention to speak in a particular language increases the activation levels of representations in the target language. This language-specific boost causes target language representations to reach threshold activation levels sooner than non-target language representations, thus preventing the non-target translation equivalent from competing for selection. This model is compatible with the finding that proficient bilinguals do not make random errors of language and yet are able to code switch with relative ease when speaking with other bilinguals (e.g., Muysken, 2000; Myers-Scotton).

The Frequency Model

In an attempt to account for evidence that monolinguals outperform bilinguals on a variety of production tasks, Gollan and colleagues have argued that being bilingual reduces the functional frequency of any given word in the bilingual lexicon (e.g., Gollan & Acenas, 2004; Gollan, Montoya & Werner, 2002). Since a bilingual has roughly double the number of lexical items in her lexicon as does a monolingual, a bilingual by default uses a given item from one language on average less often than her monolingual counterpart does. This reduction in use leads to an overall reduction in the functional frequency of lexical entries, which manifests itself as a bilingual deficit in production tasks. For example, as mentioned above, bilinguals were reliably slower to name pictures relative to age-matched monolinguals (Gollan et al., 2005), even when the bilinguals were restricted to performing the task in their dominant language. Bilinguals produced fewer category exemplars in a category-cued free recall task (Gollan et al., 2002) and suffered significantly more tip-of-the-tongue states (TOTs) than monolinguals (Gollan & Acenas), suggesting that bilinguals have greater difficulties accessing items within their lexicon. According to the competition-for-selection model, these bilingual naming "deficits" result from cross-language competition between translation equivalents (since each becomes highly activated in response to the above naming cues), which slows production and/or leads to fewer items being produced. In direct opposition to these claims, the frequency model argues that this decrement in L1 performance is not due to competition between translation equivalents, but rather is due to a reduced functional frequency of items in both languages (Gollan et al., 2005).

It is important to note that the results reported above were found with a particular group of bilinguals: heritage speakers of Spanish whose language dominance has switched to the L2 (English). Ivanova and Costa (2008) have provided additional evidence of this naming deficit with highly proficient L1-dominant bilinguals, reporting that these bilinguals were slower to name pictures in their dominant L1 relative to monolinguals. Before theoretical generalizations can be made for bilingual production more generally, further evidence is needed involving other bilingual populations.

This reduced functional frequency could be implemented in models of bilingual production through changes in the connection strengths between a conceptual representation and the corresponding translation-equivalent lexical representations in the bilingual lexicon (i.e., *the weaker links hypothesis;* Gollan et al., 2005), changes in baseline activation levels of the lexical representations, or changes in the rank order of lexical items in a list (Gollan, Montoya, Cera, & Sandoval, 2008).

The Role of Inhibition in L2 Processing

With activation spreading to both languages in parallel, competition for selection can occur at all levels of representation (see Kroll et al., 2008, for a recent review of evidence for cross-language competition, and Abutalebi & Green, 2007, for a review of the neural basis of the inhibitory mechanisms engaged during L2 production). Inhibition might facilitate selection of the target representation in the face of such competition by reducing the current activation levels of non-target competing representations, thereby reducing competition. In Green's (1998) Inhibitory Control model, inhibition is directed by the language task schema (which represent the current goals of the speaker) and is reactive in nature – that is, only after non-target representations become activated are they then inhibited to prevent them from reaching some activation threshold for selection. By this account, the amount of inhibition is directly proportionate to the relative activation levels of the target and non-target representations. It is important to note that these features of the Inhibitory Control model are quite similar to the dynamics of an inhibitory mechanism implicated in the control of memory (i.e., retrieval induced forgetting; Anderson & Spellman, 1995), which has recently been incorporated into the study of bilingual language control (Levy, McVeigh, Marful, & Anderson, 2007). The work of Anderson and his colleagues provided much of the theoretical and methodological framework for the current study and is reviewed in more detail below.

Evidence for Inhibition

Language Switch Costs

Initial empirical support for an inhibitory control mechanism was found in language switching data reported by Meuter and Allport (1999). In their seminal study, they cued bilingual participants to name digits in one of their two languages, with the language of naming varying within blocks. On a given trial, the language of naming was either the same as the language of the previous trial (*non-switch* trials) or different than the previous trial's language (*switch* trials), and was either in the participant's L1 or L2. They found that participants took reliably longer to name digits on switch trials than on non-switch trials – commonly referred to as a *switch cost*. More important, though, they found an asymmetry in switch costs, with switching into the more dominant L1 being counterintuitively more difficult than switching into the less dominant L2. The authors proposed that the greater switch costs for the L1 were driven by lingering L1 inhibition from the previous (L2 naming) trial. When naming a digit in the less dominant L2, the more dominant L1 name will become highly activated and therefore, according to the competition-for-selection model, will compete with the L2 name. In order to resolve this competition and allow successful L2 production, the L1 is inhibited globally (e.g., by inhibiting the language tasks schemas associated with that language). When switching back into the inhibited L1 on the subsequent trial, lingering inhibition slows naming in the L1 and therefore leads to a larger switch cost. However, when naming in the dominant L1, lexical candidates from the L2 compete much less with the L1 lexical candidates, and so less inhibition is needed to allow production in the L1.

This inhibitory account is captured in Green's (1998) Inhibitory Control model. Extending Norman and Shallice's (1986) model of the control of action, Green proposed two levels of bilingual control. First, the supervisory attentional system, which activates the language task schema most appropriate for the current task (e.g., *name the picture in English*), prevents naming from occurring in the non-target language by inhibiting competing or incompatible language task schemas (e.g., *name the picture in Spanish*). Second, the currently active language task schema reactively inhibits lemmas in the non-target language based on their language membership. This reactive inhibition is proportionate to the level of activation of the competing representation. That is, more highly activated non-target lemmas are inhibited to a greater extent in order to prevent them from mistakenly being produced.

Based on the claim that more highly activated lemmas in the non-target language are (reactively) inhibited more, the IC model makes specific predictions regarding the role of language dominance. For less proficient learners, the L1 is much more dominant and therefore, as outlined above, should require greater amounts of inhibition than the L2. In a language switching experiment, this would be manifest in a switch cost asymmetry, with greater switch costs for the L1. But for highly proficient bilinguals, the L1 and L2 are both highly activated and should be equally likely to compete with one another during production, and therefore similar amounts of inhibition should be expected for the L1 and the L2. Empirically, we should find equivalent switch costs in both languages. This is precisely what has been found across a number of experiments. Costa and Santesteban (2004, Experiments 1-3) had less proficient learners and highly proficient bilinguals name pictures in either their L1 or L2 in a language switching task. The learners showed the switch cost asymmetry with larger switch costs for the L1, whereas the highly proficient bilinguals showed symmetrical switch costs. Note that Costa and Santesteban reported symmetrical switch costs when their highly proficient bilinguals switched between their dominant L1 and their much weaker L3, which they argued was evidence that the non-target language did not compete for selection with these highly proficient bilinguals (see *Language-Specific Selection Mechanism Model* above). However, this effect has been difficult to replicate. Moreover, Philipp, Gade and Koch (2007) more recently found asymmetric switch costs when they asked their participants to switch between their L1 and L2, their L2 and L3, and their L1 and L3. Critically, the switch costs were always larger for the more dominant language in the language pairs, providing additional support for the competition-for-selection model.

The literature on language selection has primarily focused on the asymmetry of switch costs during language switching, with less importance given to the magnitude of the language switch cost for a given language. For example, Costa and colleagues (Costa & Santesteban, 2004; Costa et al., 2006) have argued that the symmetrical switch costs typically found with more proficient bilinguals are evidence that they no longer require inhibition to control production. However, the paradigm used by Philipp et al. (2007) allowed them to examine both the switch cost asymmetry and the n-2 repetition cost, which is considered a marker of inhibition. They found a clear dissociation between these two measures: preparation time modulated the n-2 repetition cost but not the switch cost asymmetry. Also, the asymmetry was equivalent for both strong-weak and weak-weak language pairings (cf., Costa & Santesteban, 2004; Meuter & Allport, 1999). The authors concluded that these results suggest that inhibition appears to support language switching (as evidenced both by switch costs and n-2 repetition costs), but that the switch cost asymmetry itself may not be the strongest measure of inhibition.

Immersion Learning

Linck et al. (in preparation) found converging evidence of L1 inhibition using online comprehension and production measures. Participants were native English speakers who were either immersed in an L2 environment (*immersed learners*) or studying an L2 in the classroom context only (*classroom learners*). In the translation recognition task, participants were presented a pair of words (one in the L1 and the other in the L2) and asked to indicate whether they were a correct translation pair. Thus, this comprehension measure necessarily required both languages to be active. In a critical distractor condition, the second word was an L1 lexical distractor that overlapped in form with the first word (e.g., cara—card). The classroom learners suffered significant interference from these L1 lexical form distractors, replicating previous research (e.g., Sunderman & Kroll, 2006). However, the immersed learners were entirely unaffected by the L1 form distractors, which is particularly noteworthy given the bottom-up nature of comprehension (e.g., Dijkstra & Van Heuven, 2002). On the verbal fluency task, participants were presented a category (e.g., fruits) and given thirty seconds to produce in the cued language as many examplars as possible. As expected, the immersed learners produced significantly more exemplars in Spanish, but they also produced significantly fewer exemplars in their L1 English. Taken together, these results suggest that the immersed learners were inhibiting the L1 while immersed in the L2-dominant environment. However, these L1 inhibitory effects were somewhat transient, as L1 verbal fluency performance rebounded within months of returning to an L1-dominant environment. This suggests a rather complex interplay between enduring cognitive skills that may be developed over time and more ephemeral contextual factors in determining when and how inhibitory mechanisms are engaged to support L2 processing.

Cross-language Retrieval Induced Forgetting

In another line of work, Levy and colleagues (2007) modified the retrieval practice paradigm (Anderson, Bjork & Bjork, 1994) originally designed to study the control of memory in order to examine language control in L2 learners. Since this work motivated the research design employed in the four experiments reported in this thesis, let us examine the results and interpretations in some detail. In their study, native English speakers performed mixed picture naming in English and Spanish, with each picture being named once, five times or ten times (consistently in the same language). Then, participants performed a word-plus-stem memory test in English that cued retrieval of the picture names based on either phonological cues (e.g., break—s____) or semantic cues (e.g., venom—s___, for snake). The authors then compared the proportion of items correctly recalled on the memory test as a function of the language of naming and number of repetitions during the picture naming task. In this research paradigm, the retrieval effects are measured by comparing items that were previously retrieved (i.e., names of previously named pictures) with new items (i.e., names of pictures not seen during picture naming). See Figure 1-2 for representative results from their experiments.

Note that the zero repetition condition provides the baseline of comparison for identifying facilitative or inhibitory effects.

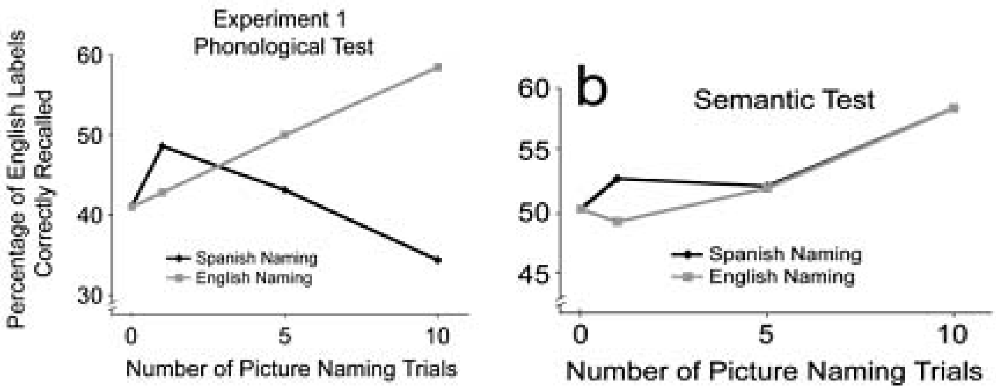

Figure 1-2: Results from the phonological test and semantic test in a bilingual retrieval practice paradigm (adapted from Levy et al., 2007).

Having named a picture in English facilitated performance on both (English only) memory tests, as evidenced by higher recall values compared with the zero repetition condition. However, having named a picture in Spanish had differential effects on the two tests, particularly for the ten Spanish repetitions condition. On the phonological test, ten repetitions of the Spanish name led to significantly reduced recall of the English picture name, as evidenced by lower recall for that condition relative to the zero repetition condition. However, on the semantic test, naming in Spanish in fact facilitated performance in a similar manner to naming in English. Levy and colleagues (2007) concluded that, since cross-language retrieval induced forgetting was found on the phonological test but not the semantic test, this is evidence that naming the pictures in Spanish induced inhibition of the English phonological representations but not the semantic representations. That is, they argued that inhibition operated at the level of the phonology. Note that these results are congruent with the claims of the competition-for-selection model, with the cross-language competition leading to the need for inhibition. However, language specific models of bilingual speech production cannot adequately account for these results. Since they assume that activated representations in the two languages do not compete for selection, there would be no need for inhibition and in fact they might instead predict that naming in the L2 should facilitate recall of the L1 representation at test.

There is reason to exert some caution in drawing strong conclusions regarding the nature and locus of inhibition. Both memory tests involved a strong metalinguistic component, requiring conscious reflection on the phonological or semantic characteristics of the cue and target words. The accuracy of recall was the only dependent measure, which may not be the best measure of inhibition since the most unambiguous definition of inhibition is a reduction in the activation level of a memory representation (Perfect, Moulin, Conway, & Perry, 2002; Veling & van Knippenberg, 2004). Moreover, it is conceivable that lingering inhibition of a memory representation could be released or overcome by some retrieval process (Bjork & Bjork, 1996; Veling & van Knippenberg), leading to successful retrieval after a short delay – which could have been detected in RT data but not in recall accuracy data. In addition, it is unclear whether the inhibition induced in this task is limited to the phonological representations. Recent research has demonstrated that orthography is activated during language production tasks even when the word itself is not visually presented (e.g., Damian & Bowers, 2003), suggesting that inhibition of the orthographic representations of the English picture names also may have contributed to the forgetting effects.

An additional issue is whether the inhibition effects reported by Levy et al. (2007) were induced by the mixed language design of the study task. Their picture naming task required both the L1 and L2 to be highly active simultaneously, which may have exaggerated the need for inhibition during production. Although the evidence reviewed above suggests that the L1 is active during L2 production which would suggest that L1 inhibition may be necessary regardless of the context of production, it is an empirical question of whether a mixed language task would modulate the presence of inhibition in this paradigm. These limitations will be addressed in the four experiments described below.

Converging Evidence for Competition and Inhibitory Control

Neuroimaging research on bilingual language control provides converging evidence that inhibitory mechanisms function to resolve competition among lexical competitors. Longworth, Keenan, Barker, Marslen-Wilson, and Tyler (2005) argued for the role of the basal ganglia in later (monolingual) language processes that require inhibition of competing alternatives – a function that could readily be applied to the case of bilingual language processing. Recent bilingual research has implicated the dorsolateral prefrontal cortex (DLPFC) as a primary neural area supporting language control (Abutalebi, 2008; Abutalebi & Green, 2007; Rodriguez-Fornells, De Diego

Balaguer, & Münte, 2006). This is further supported by research suggesting that the neural tissue that supports inhibition of motor responses, such as in a go/no-go task, also supports the control of language. According to one view, the anterior cingulate cortex (ACC) detects conflict that must be resolved and informs the DLPFC, which then exhibits control via the modulation of posterior cortical or subcortical regions (Levy & Anderson, 2002). These same brain regions have been implicated in the resolution of interference during both Stroop and Simon tasks (Peterson, Kane, Alexander, Lacadie, Skudlarski, Leung et al., 2002). Taken together, the currently available neurophysiological data suggest that similar inhibitory mechanisms support cognitive control more generally and bilingual language control in particular.

The Role of Inhibition in the Development of L2 Proficiency

Competition from the L1 during picture naming is likely to be strongest at earlier stages of L2 learning, when the L1 is much more dominant than the L2. This developmental shift in the asymmetry of cross-language competition is captured by the Revised Hierarchical Model (RHM; Kroll & Stewart, 1994), presented below in Figure 1-3. According to the RHM, when naming a picture (i.e., when cued by a conceptual cue to access the lexical entry), L2 learners initially access L2 words indirectly via the L1 words because they do not yet have a strong direct link between the conceptual store and the L2 lexicon. So, when naming a picture in the L2, the conceptual representation first activates the L1 before activating the L2 via the lexical links, thereby creating a situation where the L1 is highly activated and competes strongly for selection. As L2 proficiency increases, the direct links between the conceptual store and the L2 lexicon are strengthened and reliance on the L1 lexical representations declines (although the direct lexical links are still present and influence processing).

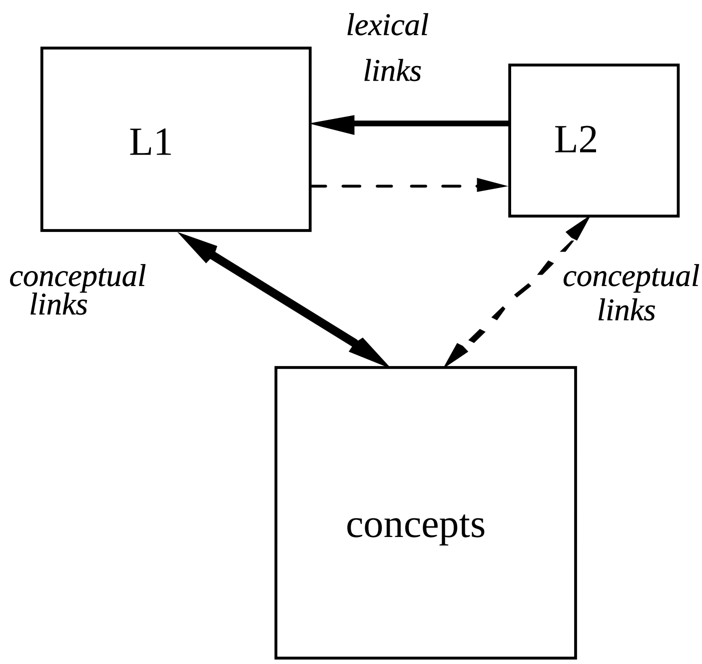

Figure 1-3: The Revised Hierarchical Model (adapted from Kroll & Stewart, 1994).

This reliance on the L1 for L2 lexical access would suggest that L1 inhibition might serve a more important role earlier in the development of L2 proficiency, when the potential for L1 competition is greatest. Evidence in support of this prediction was found by Costa and Santesteban (2004) in their language switching study involving less and more proficient Spanish-Catalan bilinguals. They replicated Meuter and Allport's (1999) switch cost asymmetry with the less proficient bilinguals but found symmetric switch costs with the balanced bilinguals. The authors concluded that inhibition serves an important role at earlier stages of L2 proficiency, but once a high degree of proficiency has been acquired in any two languages, the bilingual has developed skill in effectively controlling attention such that she no longer must rely on inhibitory mechanisms (i.e., *The language specific selection mechanism model* described above). Note that empirical support for this claim has been mixed, with symmetrical costs when switching between a strong L1 and a weaker L3 (Costa & Santesteban, 2004, Experiment 4) or a strong L2 and a weaker L3 (Costa et al., 2006, Experiment 2), but the standard asymmetrical costs when switching between a weaker L3 and L4 (Costa et al., Experiment 3). It appears that the switch cost asymmetry has less to do with the absolute proficiency level of the bilingual, as claimed by Costa and colleagues, and more to do with the relative dominance of the two languages being used (e.g., Green, 1998; Meuter & Allport, 1999).

Levy et al. (2007) reported other preliminary evidence of the changing need for L1 inhibition with increasing L2 proficiency. When separately examining the performance at test of less and more proficient learners based on their picture naming performance at study, they found L1 inhibition effects with less proficient learners but not with more proficient learners. This claim will be directly tested in the current study by including both less proficient L2 learners and highly proficient bilinguals.

Cognitive Consequences of Being Bilingual

There is a growing accumulation of evidence suggesting that a lifetime of experience juggling two languages in fact incurs cognitive benefits to the bilingual, such as enhanced executive functioning (e.g., Bialystok, Craik, Klein & Viswanathan, 2004; Colzato, Bajo, van den Wildenberg, Paolieri, Nieuwenhuis, La Heij et al., 2008).

Comparing bilinguals with age-matched monolingual counterparts, Bialystok and her colleagues have reported a bilingual advantage on a variety of tasks that require resolution of competition among alternative responses (Bialystok, Craik & Luk, 2008; Bialystok & DePape, in press; Bialystok et al., 2004). Much of this research has focused on either young children or aging adult bilinguals. However, Costa, Hernandez and Sebastián-Gallés (2008) recently reported cognitive benefits with young adult bilinguals, who are at the peak of their cognitive abilities. In particular, they found evidence of more efficient alerting and executive control functions while performing a conflict resolution task.

All of the bilinguals in the studies reported above were early bilinguals (i.e., began speaking their two languages from an early age). Recently, Linck, Hoshino & Kroll (under review) provided the first evidence of a bilingual benefit in executive functioning within a sample of late bilinguals. Comparing young adult late learners of an L2 with age-matched monolinguals, after controlling for differences in working memory capacity they found the L2 learners exhibited better inhibitory control on the Simon task. In addition, an analysis of individual differences found that inhibitory control abilities were related to the degree of cross-language activation found during an online language production task. The work reviewed above has laid the foundations for a promising area of investigation that will contribute converging sources of data on inhibitory control. It is particularly important that future work contribute to theoretical developments in constructing principled accounts of the inhibitory mechanism(s) implicated in bilingual language processing and their relation to cognitive processing more broadly.

The purpose of the current study was to further examine cross-language retrieval induced forgetting (Levy et al., 2007) to provide converging evidence on the role and locus of inhibition during bilingual speech production. Specifically, the study tested the hypothesis that naming pictures in the L2 induces inhibition of the L1 phonology. Before presenting Experiments 1 through 4, we turn now to a description of the general design and predictions of the study.

Chapter 2

General Design

The purpose of this study was to replicate and extend the findings of Levy et al. (2007) in order to examine the nature of L1 inhibition in bilingual language processing. All four experiments used a similar research design with the same set of materials. The design of the critical tasks was as follows. First, participants named pictures, some in English and others in Spanish as cued by the picture's colored background. After performing a five-minute secondary task, participants then performed an English-only lexical decision task. In the first three experiments, all with native English speakers learning Spanish, the lexical decision task at test was in the L1. In the fourth experiment, with Spanish-English bilinguals, the lexical decision was in the L2. The critical lexical decision stimuli included the English names of pictures that were named in English (hereafter referred to as *English named pictures*), English names of pictures that were named in Spanish (*Spanish named pictures*), and English names of pictures that the participants had never seen or named in the experiment (*new items*). All three sets of pictures were matched on a set of crucial lexical properties (see *Materials* below). If naming pictures in Spanish induces inhibition of the English picture name, then lexical decisions should be slower and/or less accurate for Spanish named pictures relative to unnamed pictures. That is, the consequences of naming pictures in Spanish were detected by comparing lexical decision performance for Spanish named pictures and new items.

There is a body of research demonstrating that phonological information is accessed during the lexical decision task (e.g., Bentin, 1989; Berent & Perfetti, 1995; Besner & Davelaar, 1983; Jared & Seidenberg, 1991; Pexman, Lupker & Jared, 2001; Van Orden, 1987). Although skilled readers are able to strategically shift the relative degree of reliance on orthographic versus phonological information when making lexical decisions (e.g., Martensen, Dijkstra & Maris, 2005), the research shows that phonological features impact performance in predictable ways. If Levy et al.'s (2007) claim is correct that naming pictures in the L2 induces inhibition of the L1 phonology, then the lexical decision task should potentially be sensitive to this phonological inhibition. And since both RT and accuracy data are recorded, this task should provide a more sensitive measure of inhibition than the accuracy of recall measure employed by Levy et al. (Veling & van Knippenberg, 2004).

As noted above, Experiments 1 through 3 involved native English speakers with intermediate proficiency in their L2 Spanish. Experiment 1 used a standard button-press lexical decision task. In Experiment 2, to examine whether lexical selection and/or production is required on the lexical decision task for inhibitory effects to manifest, the task was modified to a conditional word naming task (i.e., name words aloud and say "no" aloud for non-words). In both of the first two experiments, the picture naming task was language mixed, following the alternating runs paradigm (Rogers & Monsell, 1995). This design allowed an examination of language switch costs, which have been argued to reflect global inhibitory processes during bilingual language production (e.g., Meuter & Allport, 1999), as well as whether these costs reliably predict local inhibition the consequences of which would be detected in the lexical decision task. In Experiment 3, picture naming was blocked by language to test whether the addition of contextual language cues (i.e., current task goals) affected the use of inhibitory processes during naming. Finally, in Experiment 4, Spanish-English bilinguals were administered the exact procedure from Experiment 1 in order to examine the effects of picture naming on lexical decisions in the L2 (English).

Another goal of the current study was to test the claims of Levy et al. (2007) that L2 naming induced inhibition of the L1 phonology. In order to precisely identify whether inhibition is restricted to the phonological level or also operates at the orthographic level, pseudohomophones were included in the set of lexical decision materials. Pseudohomophones are legal, pronounceable letter strings that are not words in a given language but whose phonology matches the phonology of a word in that language. Previous research has found that participants make lexical decisions more slowly and/or less accurately to pseudohomophones than to control non-words (e.g., McCann, Besner & Davelaar, 1988). This *pseudohomophone effect* has been interpreted as evidence that during the course of processing, the pseudohomophone activates a phonological code that matches the phonological code of the corresponding real word, and this match in phonology impacts the participant's ability to correctly identify the pseudohomophone as a non-word. Thus, we can compare performance in the word condition in lexical decision (where phonology and orthography match completely with the English names of the previously presented pictures) with performance in the pseudohomophone condition (where phonology matches completely but orthography does not). If inhibition only occurs at the phonological level, then inhibitory effects should be present with both word and pseudohomophone stimuli to the same degree. But if L2 naming induces inhibition at both the phonological and the orthographic levels, then differential inhibitory effects should be detected with words and pseudohomophones.

General Predictions

If there is cross-language competition between the translation equivalents when naming a picture in Spanish and if this competition is resolved by inhibiting the English phonology and/or orthography, then we should see changes in lexical decision performance with the English names of pictures previously named in Spanish (i.e., Spanish named pictures) relative to unnamed pictures. The manner in which retrieval induced forgetting is measured differs for the critical words and the critical pseudohomophones. Naming pictures in Spanish (e.g., naming *mesa*) should reduce the resting activation levels of the English translation equivalent (*table*) due to the inhibition of the English name, thereby making the English names of pictures named in Spanish less readily recognizable at test. This should impair lexical decision performance for these words, as measured by slower and/or less accurate *yes* judgment latencies relative to unnamed picture names. In contrast, naming pictures in English should increase the resting activation levels of those English words, thereby making the English named picture words more readily recognizable. This should facilitate a correct lexical decision (e.g., responding *yes* for the critical word *table*, when the picture of a table was previously named in English), leading to faster and/or more accurate *yes* judgment latencies relative to the unnamed picture names. That is, the reaction time and accuracy patterns should replicate Levy et al. (2007) as well as results previously reported in studies of retrieval induced forgetting (e.g., Anderson et al., 1994; Veling & van Knippenberg, 2004).

However, for the critical pseudohomophones, the patterns should be in the opposite direction. Typically, pseudohomophones take longer to reject as non-words than matched control non-words (see, e.g., Ziegler, Jacobs, & Klüppel, 2001), due to the activation of the corresponding real word's phonological representations (e.g., the non-word *taybul* activates the same phonological representations as does the real word *table*). If naming pictures in Spanish induces inhibition of the English picture name and therefore decreases its resting activation levels, then those items' pseudohomophones should create little if any phonological interference due to the reduced activation levels of the phonological representations activated by the pseudohomophones. Thus, pseudohomophones should be easier to identify as non-words, as marked by a) faster and/or more accurate *no* judgment latencies relative to pseudohomophones of control picture names, and b) similar latencies and accuracies compared to control non-words (i.e., an elimination of the pseudohomophone effect). In contrast, if naming pictures in English increases the activation levels of those items' phonological representations, then pseudohomophones of those items should lead to greater activation of those shared phonological representations, thereby creating more phonological interference due to the salience of the corresponding word's phonology. This should make it more difficult to reject the critical pseudohomophone as a word, leading to longer and/or less accurate *no* judgment latencies relative to new pseudohomophones (i.e., pseudohomophones of pictures not previously seen or named).

To summarize the predictions, two distinct patterns are expected for words and non-words. For the word stimuli, correct *yes* responses should be similar for names of pictures not previously named (*new picture names*) and control filler words, faster for the names of pictures named in English (*English named pictures*), and slower for names of pictures named in Spanish (*Spanish named pictures*). For the non-word stimuli, correct *no* responses should be fastest for control filler non-words and pseudohomophones of pictures named in Spanish (due to the hypothesized inhibition of the English phonology), slower for pseudohomophones of new picture names, and even slower for pseudohomophones of pictures named in English.

Materials

Picture Naming

The picture naming stimuli were selected from a group of 140 electronic images of concrete objects available on the website of the International Picture Naming Project (Szekely, Jacobsen, D'Amico, Devescovi, Andonova, Herron et al., 2004). For the critical stimuli, two sets of 60 pictures were matched on eight lexical properties (of the English picture names) that have been shown to affect lexical access and picture naming latencies (e.g., Cortese & Khanna, 2007). For the practice stimuli, the remaining 20 pictures were divided into two sets of ten items also matched on the eight lexical properties. Matching was performed using the MATCH program (van Casteren & Davis, 2007). The means (and standard deviations) of the lexical properties for the practice and critical lists are presented in Table 2-1 . Independent samples *t*-tests found no differences across practice or critical lists on any lexical property (all *p*s > .20).

Table 2-1: Mean (and SD) lexical properties for the practice and critical stimulus lists of the picture naming task.

	Practice list		Critical list	
Lexical property	A	B	A	B
Word length (number of letters) [a]	4.0 (0.9)	4.5 (1.8)	5.0 (1.5)	5.0 (1.4)
Log word frequency [a]	1.5 (0.7)	1.6 (0.7)	1.5 (0.7)	1.5 (0.5)
No. of orthographic neighbors [a]	9.9 (6.5)	8.0 (6.3)	5.6 (5.9)	5.9 (6.1)
Age of acquisition [a]	268 (201)	224 (153)	253 (127)	247 (135)
Imageability [a]	415 (288)	465 (249)	559 (157)	566 (155)
Familiarity [a]	410 (284)	459 (247)	524 (150)	522 (149)
Lexical decision RT (ms) [b]	603 (43)	604 (52)	603 (58)	599 (43)
Word naming RT (ms) [b]	603 (28)	580 (26)	609 (41)	602 (38)

Note. [a] Data were compiled using the N-Watch program (Davis, 2005). [b] Normed data available through the English Lexicon Project (Balota, Yap, Cortese, Hutchison, Kessler, Loftis et al., 2007).

Within critical lists A and B, 20 items were assigned to each of three naming conditions (English, Spanish or new), thus creating three versions of each list (six lists in total). Picture item lists were counterbalanced across participants. Items sharing a first letter within a list were assigned to different languages in order to avoid onset repetition effects. For the experiments involving mixed language picture naming (Experiments 1, 2 and 4), each item was named on one non-switch trial and one switch trial during each of three picture naming blocks. The language of naming was ordered in alternating runs (Rogers & Monsell, 1995), with the additional constraint that a given picture could not be repeated until at least two more pictures were named in the same language. Within each block, the order of presentation was pseudorandomized to fit these constraints using the MIX program (van Casteren & Davis, 2006), creating three different pseudorandomized versions of each of the six critical lists. The language assignment for the two practice lists was counterbalanced across participants, and the order of naming was randomized for each participant.

Lexical Decision

For each participant, the lexical decision stimuli included a set of 30 critical words (English names of the critical pictures described above) and 30 critical pseudohomophones (non-words whose phonology overlapped with the English names of the critical pictures), 30 control filler words (i.e., words that did not correspond to any of the critical or practice picture names) and 30 control filler non-words (orthographically legal letter strings that did form a word in English). Within each picture naming condition described above (English naming, Spanish naming, and no naming), ten of the items were assigned to the word condition and the remaining ten to the pseudohomophone condition in the lexical decision task. This lead to a 3 (picture naming status: English, Spanish, new) x 2 (lexical decision stimulus type: word, pseudohomophone) experimental design for the two picture naming lists (A and B), creating twelve lexical decision stimulus lists.

The twelve lists were counterbalanced across participants to ensure that all items appeared in all conditions within each experiment.

The control filler words were selected from a larger database of English words, matched item-by-item to the critical picture names on a set of seven lexical properties similar to those used to match the picture lists (see *Picture naming* above). Items were matched using the MATCH program (van Casteren & Davis, 2007), and between-sample *t*-tests found no differences between the critical and control words on any of the seven properties (all *p*s > .10). Mean (and SD) values for these properties of the 120 critical items and their 120 matched control words are presented below in Table 2-2 .

Table 2-2: Mean (and SD) lexical properties for the critical and control filler word stimuli of the lexical decision task.

	Word stimuli	
Lexical property	Critical	Control filler
Word length (number of letters) [a]	5.0 (1.5)	5.0 (1.5)
Log word frequency [a]	1.9 (2.1)	1.9 (2.2)
Number of orthographic neighbors [a]	5.8 (6.0)	5.0 (5.0)
Lexical decision RT [b]	601 (51)	609 (34)
Lexical decision % accuracy [b]	97.5 (2.7)	97.4 (2.9)
Word naming RT [b]	606 (39)	604 (31)
Word naming % accuracy [b]	99.4 (1.6)	99.3 (2.0)

Note. RT = reaction time. [a] Data were compiled using the N-Watch program (Davis, 2005). [b] Normed data available through the English Lexicon Project (Balota et al., 2007).

For each critical picture, pseudohomophones of the English picture names were taken from published stimulus lists that provided normed lexical decision data when possible (Borowsky, Owen & Masson, 2002; Reynolds & Besner, 2005; Sumutka, 2003; Yates, Locker & Simpson, 2003). When no pseudohomophone was easily found in preexisting stimulus sets, one was created by a group of research assistants who were native English speakers. Attempts were made to use spelling patterns similar to those used in the published stimuli (e.g., substituting *ph* for *f* in the initial position of a word). All control filler non-words were selected from published stimulus lists (Borowsky et al.; Reynolds & Besner; Sumutka).

Language History Questionnaire

A questionnaire was used in order to collect data on the participants' language background. Questions requested 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. See Appendix A for more details.

Awareness Questionnaire

In order to assess whether participants noticed the relationship between the picture naming stimuli and the lexical decision stimuli, an awareness questionnaire was included in the present study. Previous research has found that the consequences of retrieval (in this study, inhibition induced during picture naming) depend on the participants' noticing that a relationship exists between the practiced and the tested items (Mulligan, 2002). Four questions were adapted from Bowers and Schacter (1990). 1. *What did you think was the purpose of the word judgment task you just completed*? 2. *What was your general strategy in judging the letter strings as words or non-words*? 3. *Did you notice any relation between the pictures you named earlier and the letter strings you just saw? If yes, please explain*. 4. *While doing the word judgment task, did you notice whether any of the words were names of the pictures you named earlier? If yes, please explain*. Most participants reported noticing this relationship (111 out of the 120 participants across all four experiments), and analyses restricted to just the aware participants showed identical patterns to the analyses including all participants. Thus, all analyses reported in this thesis will include all participants regardless of their reported awareness.

General Procedure

After completing an informed consent form, all participants were seated in front of a computer in an isolated room and tested individually. Prior to beginning the critical computer tasks, each participant completed a language history questionnaire. The experimental tasks then began. Before each computer task, the experimenter remained in the testing room while the participant performed practice trials in order to answer any questions and address any technological issues. Once the practice trials were completed, the experimenter answered any remaining questions, then instructed the participant to continue with the computer task until the on-screen instructions said to find the experimenter. The computer tasks were performed in the following order: picture naming, Simon task, lexical decision, awareness questionnaire, and finally the operation span task. The procedure for each task is described in detail below.

Picture Naming

The participants began with the picture naming task. Digital recordings of the participants' vocal responses were made in order to allow trained research assistants to score the accuracy of responses at a later time. Participants named 40 pictures – 20 in English and 20 in Spanish. The pictures were named six times across three blocks of picture naming trials (twice per block). The language of naming was cued by the color of the picture's background and followed the alternating runs paradigm (Rogers & Monsell, 1995). The pictures were presented on screen one at a time, and participants were instructed to name the picture in English if the picture's background was blue or in Spanish if the picture's background was red. Pictures remained on the screen for five seconds or until the participant made a verbal response, at which point the picture disappeared from the screen and the naming latency was recorded. If the participant did not make a verbal response during the five second presentation interval, the picture remained on the screen and the correct response was displayed in text below the picture for an additional 750 ms. The exact procedure for practice trials differed for the mixed naming and blocked naming experiments, and these differences will be noted within each particular experiment.

Simon Task

After picture naming, participants performed the Simon task (Simon & Rudell, 1969). This task was included as a measure of individual differences in inhibitory control (e.g., Bialystok, 2006; Linck et al., under review) and also served as an unrelated intervening task between the picture naming task and the lexical decision task, in which the consequences of picture naming were assessed. In the Simon task, a series of red and blue boxes were displayed on screen one at a time, and the boxes varied both in their color (red or blue, in this experiment) and their location (at fixation, left of fixation or right of fixation). Participants were instructed to respond based on the color but not the location of the box, by pressing a key either on the extreme left (the tab key, for blue) or extreme right (the backslash key, for red) side of the keyboard. Thus, three conditions were possible regarding the relation between the stimulus location and the response location. On *congruent* trials, the stimulus and response locations matched (e.g., blue box on left, requiring a left key press). On *incongruent* trials, the stimulus and response locations mismatched (e.g., red box on left, requiring a right key press). On *central* trials, the stimulus location was located in the center of the screen and thus was neither congruent nor incongruent with the response location. An extensive body of research on stimulus-response compatibility has demonstrated that response times are typically longer on incongruent trials than on congruent trials due to the mismatch between the stimulus location and the response location (see, e.g., Grosjean & Mordkoff, 2002). The magnitude of this difference is termed the *Simon effect*, and will be used here as a language-independent measure of inhibitory control.

With the participant seated approximately 36 inches from the computer screen, the boxes subtended slightly less than 1° x 1° of the visual field, and on non-central trials were presented 2° left or right of fixation. The participant first performed a block of practice trials, before beginning the three experimental blocks. The practice block included four presentations of each condition for both colors, for a total of 24 practice trials. Three experimental blocks each included seven presentations of each condition, making 42 experimental trials per block and 126 total experimental trials. In all blocks, the trials were presented in random order. Both RT and accuracy were recorded for each trial.

Lexical Decision

Participants then performed a language-specific lexical decision task in English. They were instructed to indicate as quickly and accurately as possible whether a letter string presented in the center of the screen was an English word. They were instructed to press the right button (the *p* key, on the computer keyboard) when a word was presented and the left button (the *q* key) when a non-word was presented. Prior to the presentation of the letter strings, a fixation point (+) was presented in the center of the screen for 750 ms, at which point the fixation point was replaced by a letter string. The letter string remained on screen until the participant responded with the key press, at which point it disappeared and the response latency was recorded. After an intertrial interval of 1000 ms, the next letter string was presented at fixation.

The practice block consisted of a randomly ordered set of 20 items – ten words and ten non-words. Following the practice block, the first test trial block began. The test trials included 60 words (30 critical words, 30 filler control words) and 60 non-words (30 critical pseudohomophones, 30 filler non-words), which were evenly distributed across two critical blocks of 60 items. The participant was given the opportunity to rest between blocks. Immediately following the lexical decision task, participants completed the Awareness questionnaire.

Operation Span

To measure individual differences in cognitive resources, participants performed the operation span task. The operation span task is hypothesized to measure cognitive resources available for the online processing and storage of information. Performance on this task has been found to predict the efficiency of language processing as well as reading span and speaking span tasks, while minimizing the influence of language-specific processing (e.g., Turner & Engle, 1989).

In this task, a series of simple arithmetic equations (e.g,. (4 * 2) – 1 = 7; (3 * 2) + 3 = 8) were presented one at a time. Participants were instructed to evaluate whether the equation is correct, and then as quickly and accurately as possible press the *d* key if the equation was correct or the *k* key if the equation was incorrect. Equations remained on screen for five seconds or until the participant made a response (whichever came first). Immediately following their key press, the equation disappeared from the screen and an English word was presented (e.g., father), which the participant was instructed to remember for later recall. Sets ranged in size from two to six equation-word pairs and were presented in increasing order of size with three sets of each size. After viewing the last word of a given set, the word *recall* was presented followed by a blank screen and the participant was instructed to enter with the keyboard as many of the English words from that set as they could remember. After recalling the words, they proceeded to the next set until all sets were completed.

Reaction time and accuracy data were collected for the equation judgments. For each participant, a reading span score was calculated as the total number of correctly recalled final words (out of 60 total final words) from the sentences for which correct plausibility judgments were made. The stimuli and scoring scheme were taken from Tokowicz, Michael and Kroll (2004). For the Spanish-dominant bilinguals in Experiment 4, the operation span task was performed in Spanish using Spanish translations of the Tokowicz et al. materials.

Data Cleaning Procedures

Picture Naming

Before scoring the picture naming responses for accuracy, research assistants were trained on the coding scheme and independently scored sample picture naming data from a different study. Coding agreement exceeded 91% across the four research assistants. Disagreements were discussed and the coding scheme was further clarified in order to ensure proper agreement in scoring of the experimental data. The trained research assistants then listened to the digital recordings of their assigned picture naming data and coded each response for accuracy. A response was coded as *strict correct* if the participant said the target picture name used in the matching of the materials (e.g., *hat* for a picture of a baseball hat). A response was coded as *liberal correct* if the participant used the target name (*hat*) or a synonym of the name used in the matching of the materials (e.g., *cap* instead of *hat*). Prior to analyzing the picture naming data, trials were deemed outliers if the RTs were faster than 300 ms or slower than 3000 ms and were excluded from all RT analyses. In addition, trials on which a technical error occurred (e.g., the picture disappeared before the participant could respond due to a voice-key error) were excluded from all analyses.

Lexical Decision

Trials were deemed outliers if the latencies were faster than 250 ms or slower than 2000 ms, based on a global outlier criterion for lexical decision data used elsewhere (Yates et al., 2003). For all RT analyses, outliers and incorrect responses were excluded from analyses. Outliers were also excluded from all accuracy analyses.

Analytic Treatment

The main theoretical question in the current study was whether naming pictures in Spanish would induce inhibition of the English picture names. In order to test this prediction, specific comparisons were made within the lexical decision data following established norms in the literature on retrieval induced forgetting (e.g., Anderson & Spellman, 1995). In order to detect whether naming a picture in Spanish impacted lexical access to the English picture name during lexical decisions (hereafter referred to as a *Spanish naming effect*), comparisons were made in the lexical decision data (RT and accuracy) between two item conditions: the English names of pictures named in Spanish (i.e., *Spanish named pictures*) and the English names of pictures that did not appear during picture naming (i.e., *new picture names*). The new picture names never appeared before in the experiment, thus they serve as the baseline comparison condition to examine the Spanish naming effect. In order to detect whether naming a picture in English altered the accessibility of the English picture naming during lexical decisions (hereafter referred to as an *English naming effect*), comparisons were made between the English names of pictures named in English (i.e., *English named pictures*) and the new picture names. The new picture name condition served as the critical comparison condition for assessing the effects of picture naming. Since items in the three picture naming conditions were matched on a set of important lexical properties (see *Materials* above) and the assignment of items to conditions was counterbalanced across participants, any differences across conditions in the lexical decisions data reflect changes in processing due to the previous experience of naming the items' corresponding pictures in English or Spanish.

In Chapters 3 through 6, paired-samples t-tests and ANOVAs (where appropriate) were conducted to analyze the performance measure data. In Chapter 7, multilevel modeling (MLM, an advanced regression analysis) was used to analyze individual differences in the language and cognitive measures and how they related to lexical decision performance. More specifically, the MLM analyses tested the hypotheses that *global inhibition* (i.e., picture naming switch costs) was related to *local inhibition* (i.e., cross-language retrieval induced forgetting) and that the degree of local inhibition would be accounted for by individual differences in cognitive abilities.

Item analyses will not be reported within each experiment's results section, since items were counterbalanced and therefore appeared an equal number of times in each condition. However, item effects were examined and accounted for in the multilevel models reported in Chapter 7, since this is a more parsimonious and theoretically appropriate method to analyze item effects in psycholinguistic studies (e.g., Baayen, Davidson & Bates, in press; Brysbaert, 2007).

All results are reported under the assumption that there was no evidence of unequal variances (for *t*-tests) or of a violation of sphericity (for *F*-tests), unless otherwise noted. When there was evidence of a violation of sphericity, the Greenhouse-Geisser correction was applied to the degrees of freedom. Accuracy analyses were conducted on the raw percent accuracy data, unless One-Sample Kolmogorov-Smirnov Tests found that the distribution violated assumptions of normality. For these distributions, the raw percent accuracy data were normalized using an arcsine transformation prior to analysis.

Participants

The current study included native English speakers with intermediate proficiency in the L2 Spanish (Experiments 1 – 3) and Spanish-English bilinguals living in an English-dominant environment (Experiment 4). Key characteristics for purposes of comparing the participant groups across experiments are presented in Table 2-3 . Note that across Experiments 1 – 3, the native English speakers only differ on lexical decision latencies to filler non-words, F (2,88) = 5.50, p = .006, η^2_p = .11, and marginally differ on L2 self-rated proficiency, F (2,88) = 4.86, p = .094, η^2_p = .05. Post-hoc comparisons with Bonferroni corrections found that both effects were driven by differences between Experiments 2 and 3 only (p = .004 and p = .094 for filler non-word latencies and L2 self-rated proficiency, respectively). Differences in picture naming performance will be noted in the following chapters, noting implications for comparisons of the results across experiments. Although the bilingual group overall rated themselves as Spanish dominant, t (23) = 3.25, p = .004, some bilingual participants reported being more dominant in English than in their native language Spanish. Given that one's language dominance affects online language processing (e.g., Wodniecka, Bobb, Kroll & Green, in preparation), the sample from Experiment 4 was restricted to self-reported Spanish-dominant bilinguals.

Table 2-3: Mean (and SD) values for participant characteristics across all four experiments.

	Experiment			
	1 (E) [a]	2 (E) [a]	3 (E) [b]	4 (S) [c]
Self-rated English proficiency [d]	9.9 (0.2)	9.9 (0.4)	10.0 (0)	8.2 (0.9)
Self-rated Spanish proficiency [d]	6.3 (1.3)	6.7 (1.5)	5.9 (1.4)	9.7 (0.9)
Age (years)	22.0 (4.1)	21.1 (0.8)	21.6 (1.9)	26.0 (6.3)
Years of L2 study	7.0 (3.4)	7.7 (4.0)	6.5 (3.3)	7.5 (5.2)
Simon effect [e]	32 (27)	43 (32)	42 (22)	41 (26)
Working memory [f]	49.1 (5.5)	47.8 (6.8)	48.2 (6.0)	41.4 (7.2)
Lexical decision latencies				
Control filler words	625 (99)	634 (88)	596 (66)	721 (139)
Control filler non-words	709 (112)	760 (135)	658 (119)	841 (169)
Lexical decision % accuracy				
Control filler words	97.6 (3.2)	99.0 (2.8)	98.4 (2.5)	98.4 (2.8)
Control filler non-words	98.7 (2.2)	98.8 (2.7)	97.6 (3.5)	95.5 (5.9)

Note. L2 = second language. E = native English speaker. S = native Spanish speaker. All lexical decisions were performed in English regardless of the participant's dominant language.

[a] n = 24. [b] n = 43. [c] n = 19. [d] On a scale from 1 (not proficient) to 10 (native-like). [e] Amount of interference due to mismatch of stimulus and response locations, reported in ms. [f] Number of correctly recalled words, performed in the participant's dominant language.

Chapter 3

Experiment 1: Assessing Cross-language Retrieval Induced Forgetting in a Word Recognition Task

The purpose of Experiment 1 was to replicate the results reported by Levy et al. (2007) using a lexical decision task at test that was more likely to reflect the online processing of L1 lexical information than the metalinguistic rhyme task used by Levy et al. In addition, the materials were modified to include pseudohomophones in order to directly test the claims that the inhibitory effects were localized at the level of the phonology.

Predictions

As discussed above (see *General Design)*, the inhibitory account of Levy et al.'s (2007) results leads to very specific predictions for this experiment. If L2 picture naming induces inhibition of the phonological representation of the L1 picture name, then lexical decisions to L1 words should be slower and/or less accurate for words whose pictures were named in the L2 relative to new words (i.e., an L2 naming interference effect). With the phonology inhibited, correct rejections should also be faster to pseudohomophones of pictures named in the L2 relative to new pseudohomophones. If the L1 phonology is inhibited, a homophone that sounds like the L1 name of a picture previously named in the L2 should be processed no differently than an ordinary pronounceable non-word. Thus, the robust pseudohomophone effect that has been reported in the lexical decision literature (e.g., Ziegler et al., 2001) should be absent. In contrast, naming pictures in the L1 should prime their L1 names, leading to faster lexical decisions to L1 names of pictures previously named in the L1 relative to new words (i.e., an L1 naming facilitation effect). Also, correct rejections should be slower to pseudohomophones of pictures named in the L1 relative to new pseudohomophones. We might also expect a larger standard pseudohomophone effect (i.e., slower rejections of pseudohomophones relative to pronounceable non-words) for pseudohomophones of pictures named in the L1, since the phonological representations should be primed by the L1 picture naming.

Note that the new word condition (i.e., names of pictures never seen) is the appropriate comparison condition for examining the effects of naming in the L1 or L2, due to the nature of the counterbalancing procedures and the careful matching on lexical properties during the construction of the materials (e.g., Anderson & Spellman, 1995; Levy et al., 2007).

Method

Participants

Twenty-six native English speakers at an intermediate level of proficiency in their L2 Spanish participated in Experiment 1. All participants were university students who were currently enrolled in or had previously taken university Spanish language courses. The data from one participant were lost due to technical errors, and the data were excluded from an additional participant whose low L2 picture naming accuracy (less than

60%) led to too few observations per condition to justify including in the analyses. Thus, the final sample included 24 participants.

Procedure

Before naming the critical picture naming stimuli, all participants first completed two sets of practice trials blocked by language. In the first set, ten practice pictures were named in English. In the second set, ten different practice pictures were named in Spanish. All other aspects of the experiment followed the procedure described above (see *General Procedure* in Chapter 2).

Results

Picture Naming

The data trimming procedures described under *Data Cleaning Procedures* led to the exclusion of 2.7% of picture naming trials. Data from trials on which a liberal correct response was given were included in the following RT analyses (see *method* for description of liberal correct coding scheme). RT data were analyzed using a two-factor ANOVA with the within-subjects factors of *language* (English vs. Spanish) and *trial type* (switch vs. non-switch). The mean naming latencies and percent accuracy for the four naming conditions are presented below in Table 3-1 .

Table 3-1: Means (and SDs) for reaction times (in ms) and percent accuracy from picture naming at study in Experiment 1.

Condition	RT	Acc
English (L1)		
Switch	943 (35)	94.6 (1.2)
Non-switch	874 (33)	94.7 (1.0)
Switch cost	***69***	***0.1***
Spanish (L2)		
Switch	1035 (32)	73.8 (2.3)
Non-switch	994 (30)	76.6 (2.0)
Switch cost	***41***	***2.8***

Note. RT = reaction time. Acc = % accuracy

The results show that the learners named pictures significantly faster in English than in Spanish, F (1,23) = 28.64, p < .001, η_p^2 = .56, and on non-switch trials than on switch trials, F (1,23) = 15.68, p = .001, η_p^2 = .41. However, although the overall pattern of data replicated the typical switch cost asymmetry reported in the past literature (e.g., Meuter & Allport, 1999) with a numerically larger switch cost in the L1 (69 ms) than in the L2 (41 ms), the difference was not statistically reliable in the RT analysis, F (1,23) = 2.49, p >.10, η_p^2 = .10.

In order to ensure that differences in the range of proficiency across the two languages would not lead to spurious results in the accuracy analysis, the accuracy data were first arcsine transformed and then analyzed with a 2 (language) x 2 (trial type) within-subjects ANOVA. Results confirm that participants named pictures more accurately in English than in Spanish, F (1,23) = 145.26, $p < .001$, $\eta_p^2 = .86$. However, in contrast with the RT data, no differences were found between non-switch and switch trials, F (1,23) = 2.02, $p > .10$, $\eta_p^2 = .08$, or in the magnitude of the switch cost in the L1 vs. the L2, F (1,23) = 2.52, $p > .10$, $\eta_p^2 = .10$.

Taken together, the patterns in both RT and accuracy data provide evidence from an online language processing task that these learners were in fact much less proficient in the L2 than in the L1. If in fact naming pictures in a less dominant L2 induces inhibition of the dominant L1 picture name (e.g., Levy et al., 2007), then these learners are exactly the type of participants who should show processing impairments for the L1 names of pictures named in the L2. Recall also that the lexical decision task, with both RT and accuracy measures, should provide a sensitive measure of inhibition. We turn now to the analysis of the lexical decision data to test this inhibition hypothesis.

Lexical Decision

In the critical lexical decision analyses reported below, the L1 names of pictures that were not presented during the picture naming task serve as the baseline comparison condition. The data trimming procedures described above led to the exclusion of 0.5% of lexical decision trials. Data from trials on which a correct response was given were included in the following RT analyses. RT and accuracy data were analyzed using paired-samples *t*-tests. An additional exclusion criterion was added for the subset of items whose picture was named during the picture naming task. Items were excluded from analysis if the corresponding picture was accurately named less than four times during the picture naming task. This led to the exclusion of an additional 3.1% of lexical decision trials. On average across all participants, more than 16 of the 20 pictures named in the L2 during picture naming met this criterion of four or more correct naming trials. Only two participants failed to correctly name at least 70% of the pictures in the L2 at least four times. However, the inclusion of these participants did not alter the patterns in the data or the outcome of the analyses reported below, and so they were included in all analyses.

Results from other studies suggest that one repetition is not sufficient to induce inhibition (e.g., in the study of Levy et al., 2007, one repetition in fact induced facilitation) but that four to six successful L2 naming repetitions may induce inhibition of the L1 name (personal communication, T. Bajo, May 17, 2007). Since items that had been named three times or less may not have received a sufficient number of retrieval repetitions to be inhibited but instead may have been facilitated, the inclusion of these items would have obscured any underlying inhibitory effects. Thus, this exclusion criterion was used in order to bias the present analyses towards detecting any inhibitory effects. In order to ensure that this exclusion criterion did not adversely impact the conclusions of this study, all analyses were also conducted using two other selection criteria: items whose corresponding picture was named correctly on the sixth and final repetition during picture naming, and a less restricted analysis using only the global RT outlier and lexical decision accuracy criteria (i.e., independent of picture naming performance). However, the overall pattern of results remained the same regardless of the selection criteria used. Results are therefore reported from analyses using the more theoretically and empirically justified exclusion criterion of less than four correct picture naming repetitions.

RT and percent accuracy data for the critical and control conditions in the lexical decision task are provided below in Table 3-2 . Contrary to the predictions, previously naming a picture in the L2 had no effect on RTs or accuracy in lexical decisions to the words (both *t*s < 1) or to pseudohomophones (both *t*s < 1) of those pictures' L1 names. Although no differences were detected in the analyses, if anything lexical decisions to the L1 picture names were faster for words previously named as L2 pictures relative to new words (598 ms vs. 619 ms, respectively). Naming the pictures in the L1 also had no effect on lexical decisions to words and pseudohomophones (all *t*s < 1).

Table 3-2: Means (and SDs) for reaction times (in ms) and percent accuracy from lexical decisions at test in Experiment 1.

Condition	RT	% Accuracy
Critical words		
Previously named in English	612 (118)	98.7 (3.6)
New	619 (134)	99.2 (2.8)
Previously named in Spanish	598 (122)	99.3 (3.4)
Critical pseudohomophones		
Previously named in English	702 (116)	97.0 (4.7)
New	704 (109)	97.9 (5.1)
Previously named in Spanish	713 (122)	96.7 (6.2)
Control fillers		
Words	625 (134)	97.6 (3.2)
Non-words	709 (112)	98.7 (2.2)

Note. RT = reaction time.

Due to the counterbalancing across participants of the assignment of stimuli to the various conditions, it is unlikely that the lack of facilitation and/or inhibition effects was driven by lexical feature(s) of the new items (i.e., the baseline condition). Moreover, decision latencies to the new words did not differ from the latencies to the control filler words ($t < 1$). Note that latencies were reliably longer on the filler ‘no’ trials than on the filler ‘yes’ trials, $t\ (23) = 5.25$, $p < .001$, replicating the standard slowing effect for non-words in lexical decision (e.g., Ziegler et al., 2001). However, a comparison of the new pseudohomophones with the control non-word fillers failed to show the typical pseudohomophone effect in RTs or accuracy (*t*s < 1). It could be that the presence of pseudohomophones in the stimulus list altered the processing strategies used by the participants when performing the lexical decision task (i.e., a stimulus list composition effect). This is unlikely to be the only contributing factor, given that a pseudohomophone effect of the magnitude typically reported in the literature (i.e., around 30 ms) was found with an independent sample in the norming experiment. Alternatively, the experience of having recently named pictures that correspond with the stimuli presented in the lexical decision task may have also led to a shift in strategy, whereby the participants relied upon their episodic memory to inform their lexical decisions. Indeed, a majority of the participants indicated in the awareness questionnaire that they had noticed that some pictures they had named were also used as words or pseudohomophones in the lexical decision task. Although no participant explicitly claimed to rely on this knowledge when making lexical decisions, it is entirely possible that this information primed access to the orthography and/or phonology of the words and pseudohomophones of named pictures when performing the lexical decisions.

One theoretically interesting aspect to the design of the current study is the ability to test whether a relationship exists between different measures of L1 inhibition. Specifically, we can ask whether any inhibitory or facilitatory effects in lexical decision are predicted by the degree of a switch cost asymmetry in picture naming, which has been argued to index inhibition in bilingual speech production (e.g., Meuter & Allport, 1999). Although no inhibitory effects were detected in the lexical decision task in Experiment 1, it may be that differences in lexical decision performance across the various conditions are related to the switch cost asymmetry. These and other individual difference analyses will be presented below in Chapter 6, in which the advanced regression technique of multilevel modeling was used to analyze the relationships between these and other continuous variables of interest.

Discussion

Experiment 1 was an attempt to replicate Levy et al.'s (2007) reported effect of L1 inhibition as a consequence of naming pictures in the L2 with a task at test that was an online measure of lexical processing in the L1. Twice as many observations per cell were collected relative to Levy et al.'s design, and the use of RTs as the dependent measure is argued to be a more direct, sensitive measure of inhibition (e.g,. Veling & Van Knippenberg, 2004). Moreover, a variety of exclusion criteria were implemented to ensure that any subtle inhibitory effects could be detected. Nonetheless, Experiment 1 failed to replicate the results of Levy et al. Naming pictures in the L2 produced no change in the accessibility of the L1 picture name when making lexical decisions about words and pseudohomophones. It is important to note that L1 picture naming also had no effect on lexical decision performance. Before rejecting the inhibition hypothesis, we must first consider various alternative explanations for these null results. The visual presentation of the target item itself (i.e., the L1 picture name) may have led to the release of inhibition (e.g., Bjork & Bjork, 1996), thereby preventing the detection of any inhibition during the lexical decision task. But previous work has documented such inhibitory effects using the lexical decision task (Veling & Van Knippenberg). And although the release of inhibition may eliminate any inhibitory effects when using a pure recall task, the use of RTs eliminates this issue since the release of inhibition should produce small but detectable delays in the time course of recognition. The fact that no effects were detected suggests that there may not have been sufficient power to detect any effects. But, the design does not seem to be a limiting factor since, as we will see in Chapter 4, multiple effects were detected in Experiment 2 using the same design.

Levy et al. (2007) found inhibitory effects using a measure of accuracy but not RTs on the test task. In the current study, both RTs and accuracy were recorded during the test task, and yet both the RT and accuracy data failed to show any inhibitory effects. Note that the participants were made explicitly aware of the timed nature of the lexical decision task in the task instructions, in which they were instructed to respond as quickly and accurately as possible. Since task instructions have been shown to alter decision criteria used when making lexical decisions (Wagenmakers, Ratcliff, Gomez & McKoon, 2008), it is possible that these instructions altered the processes engaged during this task relative to those engaged during the untimed phonological rhyme task of Levy et al.'s study, and somehow inhibition may have been disengaged or masked by these changes in processing.

Finally, it may also be the case that similar processes must be engaged during picture naming and lexical decision in order for inhibition to show its effects. The lexical decision task in Experiment 1 only required a button-press response and therefore did not require processing through to the level of the phonology as was required in picture naming. To further examine this issue, the experimental design was modified for Experiment 2, with the lexical decision requiring a vocal response. In this conditional word naming task, participants were now instructed to say aloud the presented letter string if it was a word or say “no” if it was a non-word. If processing through to the level of the phonology in the test task is required for inhibition to be detected, then the results of Levy et al. (2007) should be replicated in Experiment 2.

Chapter 4

Experiment 2: The Role of Lexical Selection in Detecting the Inhibitory Consequences of L2 Naming

Experiment 1 failed to replicate Levy et al.'s (2007) effect of phonological inhibition when processing at test was assessed by lexical decision in the L1. The purpose of Experiment 2 was to examine whether the inhibitory effects of repeated L2 naming are only found when subsequent processing actively engages the phonology of the L1 picture names. Although a rich body of research has demonstrated that the lexical decision task is sensitive to phonological processes (e.g., Berent & Perfetti, 1995; Besner & Davelaar, 1983; Frost, 1998), the task does not explicitly require that a phonological form be specified. One might expect, then, to see stronger inhibitory effects in a task that requires selection through to the level of the phonology. Thus, the same mixed language picture naming task was again employed during the study phase in Experiment 2, but the response mode on the lexical decision task was modified from a button-press to vocal production (i.e., conditional word naming). Specifically, for words the participants were required to name the word aloud (thereby the specification of phonology, as in the picture naming task), and for non-words the participants simply had to say "no" aloud.

Predictions

If processing through to the level of the phonology is required for inhibition to impact performance, then the conditional word naming task which requires specification of the phonology should be sufficiently sensitive to detect the inhibition of the phonology of L1 words that were previously named in Spanish. That is, the results should conform to the predictions outlined above (see *General Predictions* in Chapter 2): naming pictures in the L2 should lead to slower naming latencies for the L1 names of those pictures and faster rejections for pseudohomophones of those pictures, whereas L1 naming should lead to faster naming latencies for the names of those pictures and slower rejections for pseudohomophones of those pictures.

Method

Participants

Twenty-six native English speakers from the same participant pool as Experiment 1 participated in Experiment 2. The data from two participants were excluded due to technical errors, leading to a final sample of 24 participants.

Procedure

As in Experiment 1, participants completed two sets of practice trials blocked by language, with the English block first followed by the Spanish block. The response mode for the lexical decision task was modified to require a vocal response (i.e., conditional word naming). Participants were instructed to name aloud the letter string if it formed a word in English and to say “no” aloud if the letter string was not a word in English. Vocal responses were recorded using the same microphone and digital recorder used during the picture naming task. Following data collection, trained research assistants listened to the recordings and coded the participant responses for accuracy. All other aspects of the experiment followed the procedure described above (see *General Procedure* in Chapter 2).

Results

Picture Naming

The data were trimmed using the procedures described under *Data Cleaning Procedures*, leading to the exclusion of 2.0% of picture naming trials. Data from trials on which a liberal correct response was given were included in the following RT analyses. RT data were analyzed using a two-factor ANOVA with the within-subjects factors of *language* (English vs. Spanish) and *trial type* (switch vs. non-switch). The mean naming latencies and percent accuracy for the four naming conditions are presented below in Table 4-1 . A visual inspection of the data suggests that these learners showed the typical switch cost asymmetry, with a larger cost of switching into the L1 than into the L2 (78 ms vs. 27 ms, respectively). This pattern was confirmed by the ANOVA results. There were significant main effects of language, F (1,23) = 8.16, p = .009, η_p^2 = .26, and trial type, F (1,23) = 31.34, p < .001, η_p^2 = .58, and importantly the language x trial type interaction was significant, F (1,23) = 7.41, p = .012, η_p^2 = .24. The learners in Experiment 2 thus replicated the switch cost asymmetry in picture naming that has been reported in previous studies (e.g., Meuter & Allport, 1999) for L2 learners and bilinguals who are more proficient in the L1 than the L2.

Table 4-1: Means (and SDs) for reaction times (in ms) and percent accuracy from picture naming at study in Experiment 2.

Condition	RT	Acc
English (L1)		
Switch	951 (29)	93.7 (1.3)
Non-switch	873 (27)	95.1 (1.5)
Switch cost	***78***	***1.4***
Spanish (L2)		
Switch	998 (25)	82.3 (2.2)
Non-switch	971 (25)	83.4 (2.0)
Switch cost	***27***	***1.1***

Note. RT = reaction time. Acc = % accuracy

The arcsine transformed accuracy data were also analyzed with a 2 (language) x 2 (trial type) within-subjects ANOVA. Results confirm that participants named pictures more accurately in English than in Spanish, F (1,23) = 38.41, $p < .001$, $\eta_p^2 = .63$, and on non-switch trials than on switch trials, F (1,23) = 8.42, $p = .008$, $\eta_p^2 = .27$. The interaction failed to reach significance, $F < 1$, $\eta_p^2 = .04$.

As in Experiment 1, the patterns in the RT and accuracy data confirm that these learners are less proficient in the L2 than in the L1. Indeed, the L1 and L2 picture naming latencies are comparable across the two experiments. Note, however, that the learners in Experiment 2 did have reliably higher accuracy rates relative to the Experiment 1 learners on L2 switch trials (82% vs. 74%) and L2 non-switch trials (83% vs. 77%), t (46) = 2.59, p = .013, and t (46) = 2.85, p = .006, respectively. This difference should be kept in mind when making any comparisons of the results across the two experiments.

Conditional Word Naming

Using the same exclusion criteria described in Experiment 1, RT outliers and items which were named correctly less than four times during picture naming were excluded from the following analyses. This led to the exclusion of 6.8% of conditional word naming trials. On average across all participants, 15 of the 20 pictures named in the L2 during picture naming met this criterion of four or more correct naming trials. Eight participants failed to correctly name at least 70% of the pictures in the L2 at least four times (seven of the eight named over 65% correctly). However, the conclusions of the analyses reported below did not change when restricted only to the 16 participants meeting the 70% accuracy criterion, and so all 24 participants were included in the following analyses. Data from trials on which an incorrect response was given were also excluded from the following RT analyses. RT and accuracy data were analyzed using paired-samples *t*-tests. RT and percent accuracy data for the different conditions in the lexical decision task are provided below in Table 4-2 .

Table 4-2: Means (and SDs) for reaction times (in ms) and percent accuracy from conditional word naming at test in Experiment 2.

Condition	RT	% Accuracy
Critical words		
Previously named in English	591 (74)**	99.2 (4.1)
New	624 (116)	99.2 (4.1)
Previously named in Spanish	601 (72)	100 (0)
Critical pseudohomophones		
Previously named in English	772 (135)*	99.5 (2.3)
New	805 (146)	98.7 (3.5)
Previously named in Spanish	800 (129)	98.0 (5.6)
Control fillers		
Words	634 (88)	99.0 (2.8)
Non-words	760 (135)	98.8 (2.7)

Note. RT = reaction time. Significance values denote the critical comparison between the names or pseudohomophones of previously named pictures and new words or pseudohomophones, respectively.

* $p < .05$. ** $p < .01$.

As in Experiment 1, the results failed to support the predictions of the inhibition hypothesis. Repeatedly naming pictures in the L2 did not affect conditional word naming latencies when the L1 picture names were later presented as words to be named, $t(23) = 1.63$, $p > .10$, or as pseudohomophones, $t < 1$. An examination of the data shows that L2 picture naming at study, if anything, produced shorter L1 word naming latencies at test (601 ms vs. 624 ms for L2 named pictures vs. new words, respectively), with an almost identical magnitude of facilitation (23 ms) as was found in the lexical decision task of Experiment 1 (21 ms). In addition, naming pictures in the L1 significantly facilitated word naming latencies, t (23) = 2.99, p = .007, as well as vocal rejections to pseudohomophones, t (23) = 2.08, p = .049. For the accuracy analysis, the data were normalized using arcsine transformation. The naming status of picture names (i.e., English or Spanish naming) had no effects on word naming or pseudohomophone rejection accuracies (all *t*s < 1).

A further examination of the pseudohomophone latencies reveals another effect that directly contradicts the predictions. Naming pictures in Spanish did not reduce the pseudohomophone effect, as evidenced by reliably slower rejection latencies for pseudohomophones of pictures named in Spanish relative to control non-words, t (23) = -2.82, p = .010. However, although it was hypothesized that naming pictures in English would prime the English phonology and therefore induce an even larger pseudohomophone effect, in fact English picture naming eliminated the pseudohomophone effect entirely: pseudohomophones of pictures named in English were rejected equally as quickly as control non-words, $t < 1$.

An analysis of the control word and non-word data provides further evidence against the possibility that stimulus-specific characteristics led to the null results of Experiment 1. Correct responses were made equally quickly to the unnamed pictures and the control filler words, t (23) = 1.14, p > .10, d = .23, replicating Experiment 1. More importantly, the standard pseudohomophone effect was found in Experiment 2, with correct rejection latencies being longer to new pseudohomophones than to control non-word fillers, *t* (23) = 3.76, *p* = .001, *d* = .77.

Discussion

The purpose of Experiment 2 was to examine whether the failure to replicate the inhibitory effects of Levy et al. (2007) in Experiment 1 could be attributed to the test task not requiring processing through to the level of the phonology. The results from Experiment 2 go against such an account. Even with conditional word naming – a task that requires specification of the phonological form – no evidence of L1 inhibition was found. A comparison of the L2 named and new conditions suggests that, if anything, repeatedly naming pictures in the L2 facilitated access to the L1 picture names during the conditional word naming task. Although the results are somewhat speculative at this point due to their lack of statistical significance, the patterns in the data from Experiments 1 and 2 clearly provide evidence against the inhibition hypothesis proposed by Levy and colleagues.

The previous experience of naming pictures indeed affected word naming performance. This effect was clearest in the L1 naming condition, where significant facilitation was found in word naming latencies. That this standard within-language facilitation effect was detected suggests the experimental design was not entirely lacking statistical power. Given that cross-language facilitation effects can be of a slightly smaller magnitude than within-language effects (e.g., Costa et al., 1999), it may be that the design of Experiments 1 and 2 was below the threshold of power needed to detect the

20 ms cross-language facilitation pattern present in the RT data. This hypothesis will be tested directly in the individual differences analyses reported in Chapter 6, wherein the data from Experiments 1 and 2 will be pooled for a more robust analysis.

Considering an alternative explanation, the lack of significant results may have been driven by the fact that the lower L2 picture naming accuracy led to a smaller number of data points for the L2 named condition relative to the L1 named condition in the lexical decision task. That is, participants may have been inhibiting the L1 phonology when they successfully named pictures in the L2, but the data from participants with lower L2 proficiency (and therefore fewer data points per condition) may have masked this inhibition in the analysis. In order to test this hypothesis, an additional analysis was conducted on the data from learners with 80% or higher naming accuracy on L2 non-switch trials. For these 15 participants, the facilitation effect of 23 ms for words that had previously been named as pictures in Spanish was still non-significant, t (14) = 1.29, p = .218, whereas the facilitation due to naming pictures in English (33 ms) was still reliable, t (14) = 2.79, p = .014, therefore ruling out this hypothesis.

The presence of pseudohomophone facilitation also goes against the predictions of the study: repeated L1 naming should have facilitated access to the L1 phonology and therefore induced a *larger* pseudohomophone effect (i.e., interference). Instead, L1 naming in fact eliminated the standard pseudohomophone effect entirely (i.e., no differences were found between pseudohomophones of pictures named in English and control non-words). Moreover, with the L1 phonology more readily available, one might expect more false alarms (i.e., incorrectly naming) with the pseudohomophones. Yet L1 naming had no effect on pseudohomophone rejection accuracy. With the test task requiring activation through to the phonology, it is surprising that instead of committing more false alarms the participants were faster at correctly rejecting the pseudohomophones as words. This facilitation may reflect a post-lexical effect in the form of a shift in strategy. Indeed, previous work has demonstrated that changes in stimulus list composition (e.g., including pseudohomophones) can lead to strategic shifts in the reliance on phonological vs. orthographic information when making lexical decisions (see Gibbs & Van Orden, 1998, and Martensen et al., 2005, for alternative theoretical accounts of strategic effects in lexical decisions due to the inclusion of pseudohomophones). Naming pictures in the study task may have in fact activated the English orthographic representation, despite the word itself not being perceptually present (e.g., Hoshino, 2006). This priming of the orthographic representation could functionally increase the salience of the orthographic match (for words) or mismatch (for pseudohomophones) between the lexical decision stimulus and the English picture name, thereby facilitating lexical decision accuracies for both words and pseudohomophones. This suggests that strategic shifts in lexical decisions may be induced by the greater experimental context extending outside of the lexical decision task itself.

Why, then, have these two experiments failed to produce any inhibitory effects whatsoever? It may have to do with the nature of the picture naming task. Mixed picture naming, by its very nature, requires both languages to be continually active. Perhaps this highly bilingual context precluded the learners from completely inhibiting the L1 name when naming pictures in the L2, and thus no inhibitory effects were found. However, Levy et al. (2007) also employed mixed picture naming in their two experiments, and thus this is unlikely to be the reason for the present failures to replicate their inhibitory effects. We will return to a discussion of the implications of the null results of Experiments 1 and 2 in the General Discussion.

Before the data were collected for these two experiments, it was hypothesized that Levy et al.'s (2007) inhibitory effects were in fact induced by the mixed language context of the picture naming task. That is, by requiring both languages to be highly active, the task may have artificially created a context in which inhibition would serve as a language control mechanism in a way that is not ordinarily present during speech production in a monolingual context. In order to test this hypothesis, the picture naming design for Experiment 3 was modified to be blocked by language. The original prediction was that, by blocking rather than mixing languages, the task would no longer *require* both languages to be highly activated and thus the need for inhibition would be attenuated. However, the results from Experiments 1 and 2 do not support this interpretation of the Levy et al. results and in fact raise the question of how a blocked naming context might impact the effectiveness of inhibition as a mechanism to control language use. Recently, Bobb, Hoshino and Kroll (in press) found that when L2 learners repeatedly named pictures in the L2 in a blocked language picture naming task, these learners were able to bias language selection toward the L2 in a subsequent picture-word interference task. Importantly, the pictures were named consistently in either the L1 English or the L2 Spanish (like in the current study). Thus, it is reasonable to hypothesize that repeatedly naming pictures in the L2 during blocked picture naming could provide sufficient information regarding the desired language of naming (i.e., a sufficiently strong language cue) to allow L1 inhibition to effectively function as a language control mechanism. This hypothesis was tested in Experiment 3 by blocking the picture naming task by language.

Chapter 5

Experiment 3: The Consequences of Blocked Picture Naming at Study for L1 Inhibition at Test

The purpose of Experiment 3 was to examine whether blocking picture naming by language can provide sufficient language cues for local L1 inhibitory mechanisms to support L2 naming. Previous research has found that the L1 remains active in both mixed and blocked L2 picture naming (e.g., Kroll, Dijkstra, Janssen, & Schriefers, 2000; Kroll et al., 2006), suggesting that L1 inhibition could facilitate L2 naming even in blocked naming conditions. If blocked picture naming can provide sufficient language cues to guide language selection when pictures are repeatedly named in the L2 (Bobb et al., in press) and if these language cues can be exploited to reduce L1 competition by inhibiting specific lexical entries (i.e., the competing L1 names of the pictures being named in the L2), then the inhibitory effects reported by Levy et al. (2007) may emerge under blocked naming conditions.

Predictions

Blocking naming by language provides participants with additional contextual cues regarding the target language of production. If participants use these cues to engage local inhibitory mechanisms in order to reduce competition from specific L1 lexical entries when naming in the less dominant L2, then their data from the lexical decision task should show the predicted L1 inhibition effects: naming pictures in the L2 should lead to slower lexical decisions to the L1 picture names and faster rejections for pseudohomophones of the L1 picture names.

Method

Participants

The sample size in Experiment 3 was doubled in order to ensure adequate statistical power to detect any inhibitory effects. Fifty-four native English speakers from the same participant pool as Experiments 1 and 2 participated in Experiment 3. The data were excluded from seven participants due to technical errors during data collection and an additional four participants whose low L2 picture naming accuracy (less than 60%) led to too few observations per condition to justify including in the analyses. Thus, the final sample included 43 participants.

Procedure

The following modifications were made to the procedure. The picture naming task was blocked by language, starting first with the practice English trials followed by two blocks of critical trials named in English, then the practice Spanish trials followed by two blocks of critical trials named in Spanish. The test task was a standard button-press lexical decision task. All other aspects of the experiment followed the procedure described above (see *General Procedure* in Chapter 2).

Results

Picture Naming

The data were trimmed using the procedures described under *Data Cleaning Procedures*, leading to the exclusion of 3.7% of picture naming trials. Data from trials on which a liberal correct response was given were included in the following RT analyses. RT and accuracy data were analyzed using paired comparisons *t*-tests. The mean naming latencies and percent accuracy for English and Spanish trials are presented below in Table 5-1 . The learners were clearly more dominant in the L1 than in the L2, as evidenced by faster naming latencies, t (42) = -12.86, $p < .001$, d = 1.96, and more accurate naming, t (43) = 8.93, $p < .001$, d = 1.36.

Table 5-1: Means (and SDs) for reaction times (in ms) and percent accuracy from picture naming at study in Experiment 3.

Language	RT	Acc
English (L1)	707 (89)	96.6 (3.0)
Spanish (L2)	933 (108)	87.4 (7.6)

Note. RT = reaction time. Acc = % accuracy

Before continuing on to the analyses of the lexical decision data, let us first review the picture naming data from the three experiments (see Figure 5-1). It is important to keep in mind any differences when comparing results across experiments.

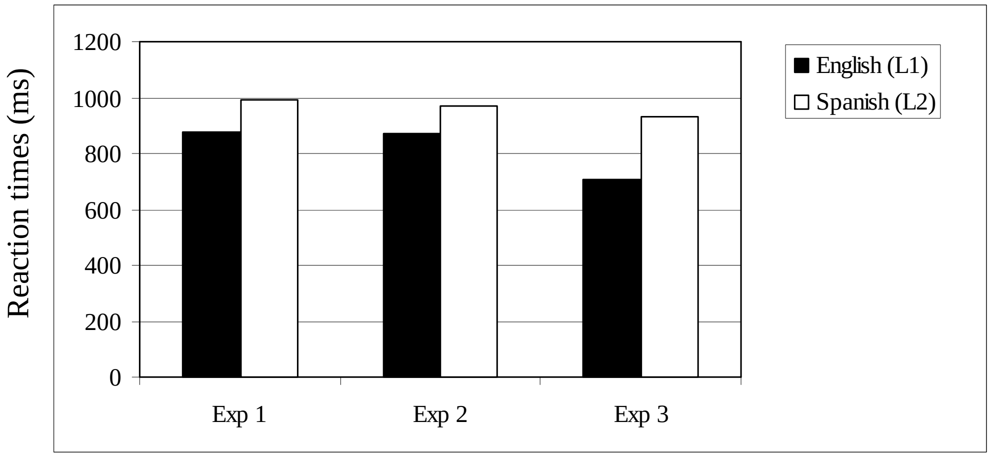

Figure 5-1: Mean English (L1) and Spanish (L2) picture naming latencies (in ms) from Experiments 1 – 3

Note. For Experiments 1 and 2 in which picture naming was mixed by language, naming latencies are reported from non-switch trials only. Experiment 3 was blocked by language and thus naming latencies are reported from all trials.

Note, for example, the differences in L1 naming latencies across experiments. When comparing the English non-switch naming latencies from Experiment 1 and 2 with the blocked English naming latencies from Experiment 3, a one-factor ANOVA shows there is a significant group effect, F (2,88) = 20.98, $p < .001$, $\eta_p^2 = .32$. Planned comparisons with the Bonferroni correction confirmed that Experiments 1 and 2 did not differ from one another (ps > .5) but were both significantly different from Experiment 3 (ps < .001). However, no differences were found in the analysis of Spanish naming latencies, F (2,88) = 2.01, $p > .10$, $\eta_p^2 = .04$. Since picture naming was blocked by language in Experiment 3, this pattern replicates the previously reported differential effect of mixing, with larger costs for the L1 than for the L2 (see, e.g., Kroll et al., 2006).

In the comparison of naming accuracy (analyzing arcsine transformed data), no group differences were found on English trials, $F\ (2,88) = 1.65$, $p > .10$, $\eta_p^2 = .04$. However, a significant group effect was found on Spanish trials, $F\ (2,88) = 11.26$, $p < .001$, $\eta_p^2 = .20$. Planned comparisons with the Bonferroni correction found that learners in Experiment 1 were reliably less accurate than those in Experiments 2 and Experiment 3 ($p = .019$ and $p < .001$, respectively). However, no difference was found between Experiments 2 and 3 ($p > .10$). The fact that these differences in L2 accuracy were found between Experiments 1 and 2, both of which involved mixed naming, suggests that they may reflect real differences in L2 proficiency. This difference will be explicitly accounted for in the individual analyses presented in Chapter 7, where L2 proficiency will be factored into the regression models before analyzing the data pooled across Experiments 1 and 2.

Lexical Decision

The exclusion criteria described above (RT outliers and items named correctly less than four times during picture naming) led to the exclusion of 3.7% of lexical decision trials. On average across all participants, 16 of the 20 pictures named in the L2 during picture naming met this criterion of four or more correct naming trials. Five participants failed to correctly name at least 70% of the pictures in the L2 at least four times. However, the data patterns and the conclusions of the analyses reported below did not change when restricted only to the 38 participants meeting the 70% accuracy criterion, and so all 43 participants were included in the following analyses. Data from trials on which an incorrect response was made were also excluded from the following RT analyses. RT and accuracy data were analyzed using paired-samples *t*-tests. RT and percent accuracy data for the different conditions in the lexical decision task are provided below in Table 5-2 .

Table 5-2: Means (and SDs) for reaction times (in ms) and percent accuracy from lexical decisions at test in Experiment 3.

Condition	RT	% Accuracy
Critical words		
Previously named in English	567 (82)	98.6 (3.6)
New	573 (87)	99.8 (1.5)
Previously named in Spanish	580 (92)	97.3 (6.0)
Critical pseudohomophones		
Previously named in English	674 (116)	97.6 (4.8)
New	676 (129)	96.0 (6.2)
Previously named in Spanish	680 (122)	96.5 (6.3)
Control fillers		
Words	596 (66)	98.4 (2.5)
Non-words	658 (119)	97.6 (3.5)

Note. RT = reaction time.

As can be seen in Table 5-2 , naming pictures in either language had no effect on lexical decision latencies or accuracy for both words and pseudohomophones (all *t*s < 1). Indeed, there was not even a hint of facilitation in the RT data from Experiment 3, which stands in direct contrast to the trends of around 20 ms of facilitation in Experiments 1 and 2.

Pseudohomophones reliably slowed correct rejections relative to non-word control fillers, t (42) = 2.70, p = .010, d = .41. However, an unexpected difference was found between new words (573 ms) and control word fillers (596 ms), t (42) = -2.70, p = .010, d = .41. It is unclear why this difference would emerge. Although one might consider the possibility that this difference affected the above analyses of the effects of repeated L1 and L2 naming, such an account should be avoided. As mentioned previously, the counterbalancing procedure used during the construction of the stimulus lists makes the new words drawn from the unnamed picture condition a more appropriate comparison condition (e.g., see Anderson & Spellman, 1995, where the no retrieval practice [NRP] condition corresponds with the new item condition).

Discussion

In Experiment 3, the picture naming task was modified to be blocked by language. The motivating hypothesis was that blocked picture naming would provide sufficiently strong contextual cues to allow an inhibitory mechanism to effectively guide language selection at study, thereby leading to the predicted inhibitory effects at test. Contrary to this prediction, repeated naming in the L1 or L2 had no consequences for the accessibility of the L1 picture names during lexical decision. Since no switching occurred during picture naming, the third experiment did not allow a direct investigation of global inhibition, whose standard measure in the literature has been the switch cost asymmetry (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999). But the similarity of L2 naming latencies in mixed and blocked conditions suggests the L1 was active across both naming conditions, replicating previous research (Kroll et al., 2006). Since these learners are likely to need to inhibit the more dominant L1 during production of the weaker L2 (e.g., Green, 1998), this could be taken as indirect evidence that the L1 was inhibited in both mixed and blocked naming to a similar degree.

The results from the first three experiments suggest that the L1 was apparently being inhibited by these learners during L2 picture naming. The switch cost asymmetry was present in both Experiments 1 and 2 (though only significant in Experiment 2), and the L1 was active to a similar degree in both mixed and blocked L2 naming conditions, as evidenced by the comparison of L2 naming latencies across the three experiments. However, neither L1 inhibition at study nor the degree of cross-language activation at study was related to L1 processing (i.e., either inhibitory or facilitatory effects) at test. Critically, the facilitation effects found in Experiment 2 demonstrate that L1 performance at test, though at a high level of proficiency, was indeed susceptible to the study manipulations such that inhibitory or facilitatory effects could have been detected in the current design. We will return to these null results and consider their implications for models of bilingual language processing in the General Discussion.

Chapter 6

Experiment 4: Cross-language Retrieval Induced Forgetting in Highly Proficient Bilinguals

Recent research suggests that, like less proficient L2 learners, even highly proficient bilinguals appear to engage inhibitory mechanisms during speech production (e.g., Abutalebi & Green, 2007; Costa et al., 2006; Kroll et al., 2008), although to a lesser extent as they become more balanced in L1 and L2 proficiency (e.g., Costa & Santesteban, 2004; Green, 1998). If similar inhibitory mechanisms support speech production for less and more proficient bilinguals, the question remains of whether highly proficient bilinguals would show evidence of cross-language retrieval induced forgetting within the current paradigm. More proficient bilinguals are likely to accurately name pictures in both the L1 and L2, and thus they should produce higher quality data within this paradigm. Moreover, these bilinguals were immersed in an L2-dominant context, which is just the kind of environment where bilinguals may become more skilled in inhibiting the L1 (Linck et al., in preparation).

To examine this question in Experiment 4, highly proficient Spanish-English bilinguals were tested using the same procedure from Experiment 1. In addition, by having proficient bilinguals perform the lexical decision task in their L2, Experiment 4 provided novel data to test whether such bilinguals inhibit the L2 during picture naming.

Predictions

If even highly proficient bilinguals engage inhibitory mechanisms during speech production, then evidence of inhibition should be found in two forms. First, participants should suffer switch costs during picture naming, with equivalent costs for the L1 and L2 due to their high degree of proficiency in both languages (e.g., Costa & Santesteban, 2004). Second, naming pictures in Spanish should induce inhibition of the English picture names, as evidenced by slower and/or less accurate lexical decisions to the names of pictures previously named in Spanish and faster and/or more accurate rejections of pseudohomophones of pictures previously named in Spanish.

Method

Participants

Twenty-five Spanish-English bilinguals participated in Experiment 4. All participants were living in an English-dominant environment in which they regularly used their L2 English in personal and/or professional contexts. The data from two participants were lost due to technical errors. Data were excluded from an additional four participants who indicated they were dominant in their L2 English, leaving a final sample size of 19 participants.

Procedure

The design from Experiment 1 was followed, with the following exceptions. Data from the language history questionnaire were used to identify the dominant language of the participant. If the participant's self-rated proficiency was equal in both languages, the participant was designated as English-dominant since they were living in an English-dominant environment. Regardless of language dominance, all communication (verbal and written) with the participant occurred in English.

Prior to the mixed language picture naming trials, the participant performed practice trials blocked by language, with in the dominant language first and the less dominant language second. For the operation span task, the to-be-remembered words were presented in the participant's dominant language. All other aspects of the materials and procedure were identical to those of Experiment 1.

Results

Picture Naming

The data trimming procedures described under *Data Trimming Procedures* led to the exclusion of 6.2% of picture naming trials. Data from trials on which a liberal correct response was given were included in the following RT analyses. The mean naming latencies and percent accuracy for the four naming conditions are presented below in Table 6-1 . For the RT analysis, a 2 (language) x 2 (trial type) within-subjects ANOVA found that switch trial latencies were reliably slower than non-switch trial latencies, *F*

(1,18) = 18.8, $p < .001$, $\eta_p^2 = .51$. However, both latencies and switch costs were comparable across languages: for the language effect, F (1,18) = 1.44, $p > .20$, $\eta_p^2 = .07$; for the language x switch cost interaction effect, F (1,18) = 2.18, $p > .10$, $\eta_p^2 = .11$. Although the switch cost in the L1 Spanish was numerically larger (suggesting the L1 was more dominant), the lack of a reliable effect interaction in the RT analysis suggests these bilinguals were quite proficient in the L2.

Table 6-1: Means (and SDs) for reaction times (in ms) and percent accuracy from picture naming at study in Experiment 4.

Condition	RT	Acc
English (L2)		
Switch	969 (52)	91.2 (1.3)
Non-switch	917 (39)	92.5 (1.4)
Switch cost	***52***	***1.3***
Spanish (L1)		
Switch	1009 (55)	84.3 (3.0)
Non-switch	923 (48)	85.8 (1.4)
Switch cost	***86***	***1.5***

Note. RT = reaction time. Acc = % accuracy

In the accuracy analysis, the results of 2 x 2 ANOVAs suggest that the bilinguals were more accurate in the L2 English than in their L1 Spanish, F (1,18) = 4.84, $p = .041$, $\eta_p^2 = .21$, and on non-switch than on switch trials, F (1,18) = 7.39, $p = .014$, $\eta_p^2 = .29$. No differences in switch costs for the two languages were found in the accuracy analysis ($F < 1$).

That RT switch costs were numerically smaller and that participants were more accurate in the L2 than in the L1 may reflect the highly L2 dominant linguistic context in which these proficient bilinguals were living. Indeed, all participants reported using English on a daily basis in both social and professional settings (i.e., school or work) and many reported using English at home. As two participants reported in the language history questionnaire, they use English "every day, everywhere." Thus, on the basis of the picture naming results and the fact that English was highly active on a daily basis, we might expect if anything that naming in the L1 might induce more inhibition and therefore lead to greater inhibitory effects on the lexical decision task than was originally predicted.

Lexical Decision

Using the same exclusion criteria described in the *General Methods*, RT outliers and items which were named correctly less than four times during picture naming were excluded from the following analyses. This led to the exclusion of 5.2% of lexical decision trials. On average across all participants, 17 of the 20 pictures named in Spanish (the L1) during picture naming met this criterion of four or more correct naming trials. Moreover, 19 of the 20 pictures named in English (the L2) met this criterion. Three participants failed to correctly name at least 70% of the pictures in Spanish at least four times, even though this was their native language. However, excluding these participants did not change the data patterns or the analysis results reported below, and so all 19 participants were included in the following analyses. Data from trials on which an incorrect response was given were also excluded from the following RT analyses. RT and accuracy data were analyzed using paired-samples *t*-tests. RT and percent accuracy data for the different conditions in the lexical decision task are provided below in Table 6-2 .

Table 6-2: Means (and SDs) for reaction times (in ms) and percent accuracy from lexical decisions at test in Experiment 4.

Condition	RT	% Accuracy
Critical words		
Previously named in English	665 (132)	99.5 (2.3)*
New	673 (91)	97.4 (4.5)
Previously named in Spanish	686 (155)	100 (0)*
Critical pseudohomophones		
Previously named in English	855 (175)	93.5 (8.1)
New	885 (207)	92.5 (8.8)
Previously named in Spanish	859 (160)	93.2 (11.5)
Control fillers		
Words	754 (228)	98.4 (2.8)
Non-words	884 (222)	95.5 (5.9)

Note. RT = reaction time.

Contrary to the predictions, naming pictures in Spanish at study did not slow lexical decisions at test to those pictures' English names ($t < 1$) or to pseudohomophones of those pictures' names ($t = 1$). However, naming pictures in Spanish at study enhanced the accuracy of lexical decisions to those pictures' English names at test, $t\ (18) = 2.53$, $p = .021$ (for arcsine transformed accuracy data). In fact, naming pictures in English at study also increased the accuracy of lexical decisions to those pictures' names at test, $t\ (18) = 2.19$, $p = .042$. No differences in response latencies at test were found for English words or pseudohomophones of pictures that were previously named in English at study (both ts < 1).

Discussion

The results of Experiment 4 at best provided partial support for the inhibitory predictions. Despite the fact that participants named pictures more accurately in the L2 than in the L1, larger switch costs were present in the L1 than the L2, although this difference in switch costs was not statistically significant. Some researchers (e.g., Costa & Santesteban, 2004; Costa et al., 2006) would argue that the lack of a significant switch cost asymmetry indicates that these proficient bilinguals in fact were not inhibiting their L1, although recent research suggests that inhibition may be present in bilinguals independent of the asymmetry in switch costs (Philipp et al., 2007).

In the analyses of lexical decision task data, the inhibition predictions were not supported. Naming pictures in Spanish at study did not impact decision latencies to either the English names of those pictures or to pseudohomophones of the English picture names at test. There was a beneficial effect of naming on the accuracy of lexical decisions which, as discussed in Experiment 2, may reflect a strategic shift in decision criteria. Since these participants were relatively proficient in both English and Spanish, the English orthographic representation for the picture names may have been primed by picture naming in both the L1 and the L2, thereby leading to the facilitation of lexical decision accuracy in both the L1 and L2 naming conditions.

In this experiment, the lack of inhibitory effects provides support for the claim that higher proficiency bilinguals do not show cross-language retrieval induced forgetting (Levy et al., 2007). Note also that no clear inhibitory effects were found during picture naming, despite the fact that these bilinguals were living in an immersion context which may in fact make them more skilled inhibitors (e.g., Linck et al., in preparation). Clearly, more research is needed to elucidate the precise boundary conditions and functional mechanisms for these inhibitory processes. We will return to this issue in more detail in the General Discussion.

Chapter 7

Analysis of Individual Differences in Experiments 1 and 2

Summary of Results Reported Above

In Experiments 1 and 2, participants named pictures in a mixed language context, and then made lexical decisions about letter strings by either pressing a button (Experiment 1) or making a vocal response (Experiment 2). In Experiment 1, previously naming a picture in the L1 or L2 did not have any significant effect on lexical decisions to the L1 picture names, and if anything L2 naming facilitated lexical decisions by approximately 21 ms. In Experiment 2, L1 naming significantly facilitated lexical decisions by 33 ms, and again L2 naming produced a statistically non-significant facilitation effect of 23 ms. Although the effects of L2 naming were statistically unreliable, the patterns in the RT data suggest there may be a beneficial and not inhibitory effect for subsequent access to the corresponding L1 lexical entry (cf. Levy et al., 2007). The purpose of the analyses reported in this Chapter is to determine whether a select group of both linguistic and cognitive individual difference variables reliably account for variance in the effects of L1 and L2 naming on lexical decision performance.

In the individual difference analyses reported below, the data were pooled across Experiments 1 and 2 in order to increase statistical power for purposes of detecting these more subtle interaction effects. The critical analyses were performed using multilevel modeling (MLM), an advanced regression technique that has advantages over traditional ANOVA analyses (see below). Dichotomous dependent variables (e.g., decision accuracy on a given trial) cannot be analyzed using the MLM approach without first aggregating accuracy data, so for simplicity of interpretation of the results the accuracy data were excluded from the critical analyses reported below. Since the most consistent RT patterns in the current study were facilitation effects in the word condition of the lexical decision task, all individual difference analyses were performed on critical word stimuli only (i.e., pseudohomophones were excluded).

The Benefits of Multilevel Modeling

Multilevel modeling (MLM) provides an alternative, more powerful analytic tool that brings with it many advantages over traditional ANOVA. MLM allows subject and item effects to be accounted for in the same analysis, providing a theoretically grounded solution to the “language as fixed effect fallacy” (e.g., Brysbaert, 2007; Hoffman & Rovine, 2007). Analyses are performed on the original raw data rather than aggregated data, eliminating the potential for missing data to negatively impact the analysis. Compared with typical ANCOVA analyses, the use of continuous variables as predictors is more straightforward in MLM analyses and requires fewer assumptions regarding the nature of those predictors. For example, in ANCOVA analyses, the magnitude of a continuous predictor’s effect is assumed to be constant across all levels of the categorical factor(s). If this assumption is violated, then the validity of that analysis is placed in jeopardy. However, MLM analyses do not require this assumption.

Moreover, this interaction between continuous and categorical factors can be explicitly built into the regression model if desired. This is particularly important in the present study, since there are many continuous variables which will serve as predictors of lexical decision performance in the following analyses, including L1 and L2 switch cost RTs, self-rated L2 proficiency, and the cognitive measures of working memory capacity and the Simon effect.

Comparing ANOVA and MLM Analyses of the Present Data

Prior to conducting the analyses of individual differences, the pooled RT data were reanalyzed to test whether the two groups differed in their lexical decision performance. A mixed factors ANOVA was conducted, with the between subjects factor of Experiment (1 vs. 2) and the within-subjects factor of naming status (English vs. none, or Spanish vs. none). Decision latencies were significantly faster for L2 named pictures than for unnamed pictures (600 ms vs. 622 ms, respectively), F (1,46) = 4.05, p = .050, η_p^2 = .08. The two groups showed no differences in performance (for both the main effect of Experiment and the Experiment x naming status interaction, Fs < 1). Decision latencies were marginally faster for L1 named pictures than for unnamed pictures (602 ms vs. 622 ms, respectively), F (1,46) = 3.08, p = .086., η_p^2 = .06. Again, group differences were not detected, with the main effect of Experiment and its interaction with naming status failing to reach significance (both ps > .20)

Note that, with greater statistical power in the analysis of the pooled data from Experiments 1 and 2, a different pattern of results was found than what was previously reported in each experiment's individual analysis. In both experiments, no effects of L2 naming were found in the lexical decision data, yet in the pooled analysis a reliable facilitation effect was found. And in Experiment 2 (but not Experiment 1), naming pictures in the L1 significantly facilitated lexical decisions, whereas in the pooled analysis this effect was only marginally significant.

To examine the comparability of results, the above analyses were also conducted using the MLM technique. The same pattern of results found using ANOVAs was obtained in the MLM analyses, which explicitly accounted for variance attributable to subjects and items. Decision latencies were marginally faster to L2 named pictures than to new words, F (1,800.6) = 3.57, p = .059. The effect of Experiment and its interaction with naming status failed to account for any significant variance in the model (both Fs < 1), and they were removed from any subsequent models. For L1 named pictures, participants responded more quickly relative to new words, but this difference was only marginally significant, F (1,832.8) = 3.27, p = .071. As with the ANOVA analysis, no significant effects were detected for the factor of Experiment (F < 1) and its interaction with naming status, F (1,770.3) = 1.53, p = .217.

Determining the Factor Structure of the MLM Regression Models

Before performing the analyses of individual differences, the appropriate factor structure must be determined separately for the analyses of L2 named pictures and L1 named pictures. First, preliminary regression models were conducted to identify which random effects should be included in the more advanced models (e.g., Locker, Hoffman

& Bovaird, 2007). For the analyses of L2 named pictures, the random effect of subjects accounted for 26.2% of error variance ($p < .001$) and was included in all future models, but the random effect of items did not account for a significant amount of variance ($p > .20$) and was therefore eliminated from all future models. For the analyses of L1 named pictures, the random effect of subjects accounted for 23.2% of error variance ($p < .001$), and the random effect of items accounted for 4.0% of error variance ($p = .049$). Thus, both random effects were included in all future models. Since no reliable experiment differences were found in the pooled data using ANOVA or MLM techniques, the Experiment factor was excluded from all individual difference analyses in order to improve parsimony and reduce the number of parameters in the regression models. Thus, the base regression models contained the following factors: for analyzing L2 named pictures, the random effect of subjects and main effect of naming status (previously named in Spanish vs. new words); for analyzing L1 named pictures, the random effects of subjects and items plus the main effect of naming status (previously named in English vs. new words).

Predictions for Analyses of Individual Differences

The following MLM analyses were conducted to examine whether the effects of L1 and L2 naming on lexical decision performance were predicted by a set of crucial individual difference factors. Each prediction is presented in turn.

L2 Proficiency

For less proficient L2 learners, the more dominant L1 should compete strongly when attempting to name a picture in the L2. With more competition present, less proficient L2 learners might rely more heavily on inhibition to support successful L2 naming (e.g., Costa et al., 2006). Indeed, Levy et al. (2007) found in post-hoc analyses that less proficient L2 learners showed more evidence of L1 inhibition following picture naming compared with more proficient L2 learners. If L2 proficiency affects the need for local inhibition during picture naming, then we would predict the following:

One's L2 proficiency modulates the effect that repeated picture naming has on lexical decision performance (as indicated by interference).

Switch Costs

The literature on language switch costs has primarily focused on the asymmetry of switch costs as an indicator of L1 inhibition (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999). Yet results from recent language switching studies suggest that examining the asymmetry per se may not be the best means to adjudicate between inhibitory and non-inhibitory accounts of language selection. Finkbeiner, Almeida et al. (2006) have argued that the switch cost asymmetry is the result of the bivalence of stimuli used in these tasks and not of inhibition. Gollan and Ferreira (2007) reported symmetrical switch costs with L1 dominant learners (who usually show the switch cost asymmetry) when these learners were able to choose the language of production during a language switching task. Moreover, Philipp et al. (2007) documented a dissociation between the switch cost asymmetry and an independent measure of inhibition (n-2 repetition costs). Thus, the language switch cost in the L1 or L2 may reflect lingering inhibition of that language (Green, 1998) independent of the presence or absence of a switch cost asymmetry (Kroll et al., 2008; Philipp et al.; Wodniecka et al., in preparation). In order to directly address this using the current data set, initial regression models included the magnitude of the L1 and L2 switch costs as well as the magnitude of the switch cost asymmetry as independent predictors.

It is possible that individuals who are better able to globally inhibit the non-target language might also be better equipped to engage local inhibitory mechanisms to resolve cross-language competition. If this is the case, then we would predict the following:

> *The magnitude of language switch costs (i.e., global inhibition) predicts the degree of interference (or facilitation) on the lexical decision task (i.e., local inhibition).*

Cognitive Abilities

Previous research has demonstrated that individual differences in working memory capacity are related to L2 processing (e.g., Michael & Gollan, 2005). There is preliminary evidence that inhibitory control abilities (as measured by the Simon task) are related to the degree of cross-language activation during online L2 processing tasks (Linck et al., under review). Since working memory and Simon tasks were included in the present study, we can examine whether differences in cognitive abilities affect one's ability to engage local inhibition:

WM and/or Simon predict the magnitude of facilitation/interference on the lexical decision task.

Results

In all of the following MLM analyses, the critical individual difference factors (and their interactions with naming status) were added to the base regression models determined above.

L2 Proficiency

To examine L2 proficiency, three factors and their interactions with naming status were added to the base regression model: self-rated L2 proficiency, ranging from 1 (not proficient) to 10 (native-like proficiency); and mean picture naming RT for non-switch L2 trials; and mean accuracy in picture naming for non-switch L2 trials. The parameter estimates from the MLM analyses of L2 named pictures and L1 named pictures are presented in Table 7-1 . In both analyses, no interactions with naming status were significant, suggesting that L2 proficiency did not predict the magnitude of the naming effects on lexical decision latencies. These learners were recruited to participate since they were at a similar level of L2 proficiency. It is possible that range restriction in the variability of L2 proficiency across participants prevented any reliable proficiency effects from emerging in these analyses.

Table 7-1: Estimated coefficients (and SEs) from multilevel modeling analyses of the effects of L2 proficiency on cross-language retrieval induced forgetting.

	Language of naming	
Parameter	L2	L1
Naming Status	-105.42 (132.53)	7.60 (128.33)
L2 Self-rated Proficiency	26.79 (9.37) **	25.57 (9.64) **
L2 Non-switch RT	0.50 (0.10) **	0.49 (0.10) **
L2 Non-switch Accuracy	-0.69 (1.26)	-0.69 (1.29)
L2 Self-rated Prof x Naming Status	-8.30 (8.52)	-8.65 (8.40)
L2 Non-switch RT x Naming Status	0.02 (0.09)	-0.10 (0.08)
L2 Non-switch Accuracy x Naming Status	1.45 (1.16)	1.60 (1.13)

Note. Analyses were conducted separately on the names of pictures previously named in Spanish (L2) and names of pictures previously named in English (L1).

* $p < .05$. ** $p < .01$.

Switch Costs

Since individuals with slower L2 naming RTs are likely to have larger switch costs, the two L2 proficiency parameters (self-rated L2 proficiency and L2 non-switch trial RTs) were left in the following regression models. This model structure was used in order to ensure that any L1 or L2 switch cost effects were accounting for unique variance above and beyond what is explained simply by L2 proficiency. Three main factors and their interactions with naming status were added to the L2 proficiency regression models: L1 RT switch cost, L2 RT switch cost, and switch cost asymmetry. However, L2 non-switch accuracy, switch cost asymmetry and its interaction with naming status did not reliably capture any variance, thus their parameters were dropped from the following models in order to enhance the fit of the models and improve parsimony.

The final factor structure and the corresponding parameter estimates from the MLM analyses of L2 named pictures and L1 named pictures are presented in Table 7-2. Looking at the effect of naming pictures in the L2 (i.e., the cross-language facilitation effect), a larger L2 switch cost significantly predicted an increase in L1 facilitation on lexical decisions. That is, the more the participant was inhibiting the L2 during picture naming (or alternatively, the more the participant was directing attention away from the L2) as evidenced by switch costs, the more cross-language activation spread to the L1 picture name thereby leading to a larger magnitude of facilitation on the lexical decision task. Looking at the effect of naming pictures in the L1 English (i.e., within-language facilitation), a larger L1 switch cost significantly predicted more facilitation on L1 lexical decisions. That is, the lexical decision performance of learners exhibiting more global inhibition of the L1 during picture naming benefited more from the repeated picture naming in the L1. Perhaps overcoming the lingering global inhibition in order to successfully name the picture in the L1 required more processing and therefore more highly activated that particular item, rendering it even more accessible during the lexical decision task. It is important to note that both of these switch cost effects were found after controlling for differences in L2 proficiency, including a measure of L2 picture naming latencies. Including the switch cost parameters significantly improved the fit of the regression models, explaining a significant proportion of variance above and beyond that explained by L2 proficiency.

Table 7-2: Estimated coefficients (and SEs) from multilevel modeling analyses of the effects of L1 and L2 switch costs on cross-language retrieval induced forgetting.

	Language of naming	
Parameter	L2	L1
Naming Status	15.20 (18.21)	27.40 (18.20)
L2 Self-rated Proficiency	26.25 (7.79) **	24.99 (7.94) **
L2 Non-switch RT	0.61 (0.09) **	0.55 (0.09) **
L1 RT Switch Cost	-0.06 (0.22)	-0.03 (0.23)
L2 RT Switch Cost	0.57 (0.15) **	0.55 (0.16) **
L1 RT Switch Cost x Naming Status	-0.37 (0.20)	-0.57 (0.20) **
L2 RT Switch Cost x Naming Status	-0.29 (0.14) *	-0.17 (0.14)

Note. Switch cost is the RT difference (in ms) between switch and non-switch trials in picture naming. Analyses were conducted separately on the names of pictures previously named in Spanish (L2) and names of pictures previously named in English (L1).

* $p < .05$. ** $p < .01$.

Cognitive Abilities

To examine whether cognitive abilities predicted the naming effects, the two main factors of working memory and Simon effect and their interactions with naming status were added to the base regression models. The parameter estimates from the MLM analyses of lexical decision performance on L2 named pictures and L1 named pictures are presented in Table 7-3 . In the analysis of L2 named pictures, no factor predicted lexical decision latencies. However, the effect of L1 naming on lexical decisions was reliably predicted by differences in working memory capacity, such that individuals with greater memory resources showed less facilitation in lexical decisions.

Table 7-3: Estimated coefficients (and SEs) from multilevel modeling analyses of the effects of cognitive abilities on cross-language retrieval induced forgetting.

	Language of naming	
Parameter	L2	L1
Naming Status	-45.78 (95.69)	-209.41 (92.62) *
Working Memory	-4.57 (2.62)	-4.50 (2.59)
Simon Effect	-0.07 (0.54)	-0.06 (0.53)
Working memory x Naming Status	0.48 (1.91)	3.90 (1.84) *
Simon Effect x Naming Status	0.03 (0.39)	0.01 (0.38)

Note. Working memory = number of word correctly recalled (out of 60) on Operation Span task. Simon effect = degree of slowing due to mismatch of stimulus and response locations (in ms) on Simon task.

* $p < .05$.

Discussion

Multilevel modeling (MLM) analyses were performed to identify which, if any, individual differences reliably predicted the magnitude of the naming effects in the lexical decision data. The analyses revealed a few key results. First, counter to the predictions, L2 proficiency did not account for differences in the effect of naming (cf. Levy et al., 2007, who reported a proficiency effect). It is important to remember that the direction of the naming effect of the current study was opposite that reported by Levy and colleagues and that L2 proficiency was operationalized differently in the current study. In their analysis of L2 proficiency, Levy et al. categorized their participants as less or more proficient simply based on the difference in L1 and L2 naming latencies (across both switch and non-switch trials) during the picture naming task, with a larger difference indicating a lower level of L2 proficiency. In the models reported above, L2 proficiency was instead accounted for by both on-line and off-line measures of proficiency – namely, L2 non-switch naming latencies and self-rated proficiency in the L2, both independent of the L1. It may be that, in fact, L2 proficiency matters under conditions where inhibitory effects are found but plays less of a role under conditions where facilitation is present.

L1 and L2 switch costs were analyzed independently of one another rather than looking only at the switch cost asymmetry, and a clear dissociation between the two switch cost measures was found. L2 switch costs predicted the effect of L2 naming on lexical decisions, with a greater switch cost (i.e., more L2 global inhibition) predicting more cross-language facilitation of the L1 names as a consequence of previously naming pictures in the L2. And switch costs in the L1 predicted the effect of L1 naming on lexical decision latencies, with a greater switch cost (i.e., more L1 global inhibition) predicting more within-language facilitation of the L1 picture name. These results completely go against the predictions. Global inhibition (as reflected by language switch costs) was found to be inversely related to local inhibition (as reflected by the non-replicated cross-language retrieval induced forgetting). That is, learners who were globally inhibiting the non-target language more at study in fact showed less local inhibition of the English picture name at test. It is particularly noteworthy that both L1 and L2 global inhibition each predicted the degree of facilitation at test, providing further evidence that the analysis of L1 and L2 switch costs and not simply the switch cost asymmetry may be a more informative approach in the study of bilingual speech production (e.g., Kroll et al., 2008). Given that facilitation and not inhibition effects were found in the present study, it will be important in future work to more closely examine the relationship between global and local inhibition under conditions where inhibition is in fact operating.

Chapter 8

General Discussion and Conclusions

The purpose of this study was to examine the nature of inhibition in bilingual speech production. In particular, this study aimed to replicate Levy et al.'s (2007) finding that naming pictures in the less dominant L2 induced inhibition of the dominant L1 at the level of the phonology. In four experiments, L2 learners (Experiments 1 – 3) or highly proficient bilinguals (Experiment 4) named a series of pictures in English and Spanish, and then they performed a lexical decision task in English to test the prediction that naming pictures in Spanish would induce inhibition of the English phonology.

Summary of Results

All four experiments failed to replicate the inhibitory effects reported by Levy et al. (2007). In Experiment 1, L2 learners named pictures in a mixed language context at study and then performed a button-press lexical decision task at test. Picture naming had no effect on the accessibility of the L1 picture names at test. In fact, if anything, naming pictures in the L2 facilitated lexical decision latencies by around 20 ms, though this effect failed to reach significance. In Experiment 2, the lexical decision task was modified to require a vocal response to test the hypothesis that inhibition would only manifest on a task that required specification of the phonological form. Naming pictures in Spanish at study did not induce inhibition of those pictures' English names. Rather, as in Experiment 1, there was a non-significant trend of around 20 ms of facilitation. Critically, naming pictures in English significantly facilitated lexical decision latencies to both words and pseudohomophones, demonstrating that this paradigm was not insensitive to the effects of picture naming.

In Experiment 3, picture naming was blocked by language in order to examine whether a blocked naming context could provide sufficiently strong language cues to guide language selection. However, picture naming at study had no effect on lexical decisions at test for both the English and Spanish naming conditions. Finally, in Experiment 4, highly proficient Spanish-English bilinguals immersed in an L2-dominant context performed the same tasks used in Experiment 1 (i.e., mixed picture naming at study and button-press lexical decision at test) in order to test whether inhibitory effects would be found with individuals who are more skilled in both languages. No effects of naming were found in the decision latencies, although decisions were more accurate to names of pictures previously named in both English and Spanish.

Potential Sources of Failures to Replicate

Before considering the implications of these results for models of bilingual speech production, it is important to consider some potential sources of the failures to replicate the inhibitory effect. Let us begin with a review of the various modifications to the methodology, starting with the picture naming task and then turning to lexical decision task.

Picture Naming at Study

Like the Levy et al. (2007) study, pictures were consistently named in the same language for a given participant. However, one critical difference is the number of naming repetitions. In the current study, all pictures were named six times in total, whereas in the Levy et al. design the number of picture naming repetitions varied across items at either one, five or ten repetitions. Although the participants were not explicitly told they would name each picture six times or that each picture would be consistently named in the same language, it is possible that the consistent number of repetitions and the consistent language of naming in the current design somehow altered processing during picture naming, perhaps by providing an additional language cue that could guide language selection. But given that pictures were also named consistently in the same language in the Levy et al. study, it is unclear why the inconsistent number of repetitions would induce inhibitory effects.

Considering the number of repetitions, note that Levy et al. (2007) found that the effect of naming pictures in Spanish varied with the number of naming repetitions. They found that ten naming repetitions induced inhibition, whereas only one Spanish naming repetition in fact induced facilitation and five Spanish naming repetitions neither facilitated nor inhibited performance (i.e., fell somewhere between facilitation and inhibition). The analyses reported above were restricted to those items whose corresponding picture had been successfully named at least four times during picture naming, which corresponds more closely to the five repetition condition of the Levy et al. study. It is possible that six repetitions did not induce inhibition because there simply were not a sufficient number of retrieval repetitions. Conflicting results have been found in other as of yet unpublished studies involving L2 learners, where five naming repetitions in the L2 sufficed to induce inhibition of the L1 (personal communication, T. Bajo, May 17, 2007). The number and consistency of naming repetitions clearly is a key issue that must continue to be examined in future research using this paradigm.

Recent research suggests that even two repetitions of picture naming may suffice to constrain activation to the target language only (Bobb et al., in press). Perhaps after six repetitions, these constraints limit cross-language competition to the point that inhibition is no longer needed. This could explain why Levy et al. (2007) found that five repetitions in the L2 did not have any effects on the L1. Moreover, such an account might also account for the results of the current study, if we assume that cross-language competition was reduced but not entirely eliminated. That is, if activation of the non-target L1 were attenuated but still present to some degree, then the degree of cross-language competition may have been reduced to the point that no inhibition was necessary to overcome the activation of the non-target L1 representations. The residual cross-language activation would remain (having not been inhibited) and make retrieval of the L1 name at test easier, therefore causing the non-significant facilitation effects. However, such an account would also predict facilitation following ten repetitions, which is precisely the condition in which Levy et al. found inhibition. Thus, although this account may explain the results of the current study, it would fail to account for the full range of effects including, critically, the cross-language retrieval induced forgetting effects that motivated the current study.

Prior to the picture naming task, Levy et al. (2007) trained their participants on the Spanish names of the pictures by presenting each picture along with its Spanish name for five seconds. The motivation for this procedure was to refresh the picture names for the participants to ensure they could accurately name the pictures. However, this component of the design may have in fact exaggerated any inhibitory effects by drawing attention to the dichotomous relationship between the cross-language competitors. It may be the case that the inhibitory effects emerged as a consequence of this training phase, in which two responses (i.e., the English and Spanish names) became strongly associated with each picture. This is not to say that cross-language competition was created by this procedure, but rather the competition and therefore the need for inhibition may have been magnified by virtue of drawing attention to the alternative, competing picture names.

Lexical Decision at Test

The lexical decision task is a lexical processing task requiring recognition only, whereas the phonological rhyme task used by Levy et al. (2007) required retrieval processes. It may be that active retrieval is required for cross-language retrieval induced forgetting effects to emerge. But, the standard retrieval induced forgetting effect has been found previously using the lexical decision task (Veling & van Knippenberg, 2004). Moreover, Perfect et al. (2002) argued against such an account, reporting evidence that retrieval induced was present when using a category verification task (which did not require retrieval) but absent when using a word-stem completion task (which may involve some top-down retrieval process). The authors concluded that active retrieval is not necessary for retrieval to induce inhibition.

There is still considerable debate regarding retrieval induced forgetting (e.g., Butler, Williams, Zacks & Maki, 2001; MacLeod & Macrae, 2001; Williams & Zacks, 2001), including the level of representation that is inhibited. Perfect et al. (2002) noted that retrieval induced forgetting had only been reported in conceptually-mediated tasks, and thus the authors concluded that inhibition is restricted to the conceptual level and does not affect the lexical representations. But more recently, using a perceptually-driven task that required lexical but not conceptual processing, Bajo, Gómez-Ariza, Fernandez and Marful (2006) did find retrieval induced forgetting, suggesting that conceptual mediation is not necessary and that inhibition can indeed affect the lexical level of representation. Recall also that Levy et al. (2007) found cross-language facilitation when participants were cued with a semantic probe. Thus, it seems unlikely that retrieval induced inhibition is restricted to the conceptual level.

The inhibitory effect reported by Levy et al. (2007) was found in accuracy of recall, whereas the analyses of the current study included both response latencies and accuracies. There is clear evidence that standard retrieval induced forgetting is robust in both accuracy and latency measures (Perfect et al., 2002; Veling & van Knippenberg, 2004). Whether this holds for cross-language retrieval induced forgetting is an empirical question that has not yet been addressed in the literature. To my knowledge, this is the first study to address this question empirically. Given that no retrieval induced forgetting effects were found in the accuracy data of the current study, it is difficult to conclude from the current results whether cross-language effects would emerge in the analysis of latencies.

An additional consideration is the mixture of words and pseudohomophones in the stimulus list of the lexical decision task. In Levy et al.'s (2007) study, the critical items at test were all L1 words: names of the critical pictures and filler words. In the current study, both words and pseudohomophones were included at test. There is some evidence that the presence of pseudohomophones can induce a strategic de-emphasis of phonological processing when making lexical decisions (e.g., Davelaar, Coltheart, Besner & Jonasson, 1978; Gibbs & Van Orden, 1998; Martensen et al., 2005; see Pexman et al., 2001, for a review). Since Levy et al. concluded that the inhibition occurred at the phonological level, a strategic shift away from relying on phonological information during the lexical decision task could have prevented any phonological inhibition of the L1 picture names from impacting performance at test. If that were the case, then we might predict inhibitory effects to be found for the L1 names of pictures named in the L2 in the absence of any pseudohomophones. Although this is an empirical question that could be addressed in future research, the pseudohomophone data from the current study go against this explanation. The pseudohomophone results and their implications for the conclusions of the current study will be considered in detail below.

As a final point, some might argue that the lack of inhibitory effects in the present study was caused by some combination of factors that rendered the design incapable of detecting any effects of the manipulations. Yet, significant facilitation effects were found in Experiment 2 for the names of pictures that had previously been named in English, demonstrating that the design was indeed sensitive to changes in performance at test as a consequence of the manipulations at study. Moreover, despite the fact that lexical decisions were made in the L1 in Experiments 1 – 3, facilitation was present in the latency data, which suggests that these participants were not performing at ceiling such that there was no room for any effect of prior picture naming to emerge. Indeed, performance at test was susceptible to long-term effects from retrieval at study. We turn now to a discussion of these long-term effects of retrieval and their implications for this study.

Accounting for Levy et al.'s (2007) Results

Given the failures to replicate the effects reported by Levy et al. (2007), it is worth considering whether alternative explanations can account for their results. First, let us look at the processing engaged at test. In their phonological rhyme task at test, the participants were asked to actively search their lexicon for items that met the criterion of rhyming with the cue. The cue provides both orthographic and phonological information, which activates multiple representations (namely, orthographic and phonological neighbors of the cue) as the search proceeds. With various representations increasing in activation, the participant would likely need to set a stringent threshold for selection in order to prevent lexical entries that only partially met the criterion from incorrectly being retrieved. Compare this to the lexical decision task, in which the target orthographic form to be selected within the lexicon is explicitly presented. Although orthographic neighbors are also activated, the target form itself is the cue, and thus a lower selection threshold may function to allow faster decisions. The presence of inhibitory effects on the phonological rhyme task but not the lexical decision task may simply be a function of the threshold for selection: inhibitory effects may have been more apparent on the phonological rhyme task because the threshold for selection was higher, and therefore the activation levels of the inhibited English names of pictures previously named in Spanish were reduced to a level below the threshold.

Another factor worth considering is the range in performance accuracy at test. On the lexical decision task of the current study, participant accuracies at test were nearly at ceiling, with mean values ranging from 95% to 99% correct. But on the phonological rhyme task of Levy et al.'s (2007) study, accuracy values ranged from 35% to around 80%. With substantially lower overall accuracy, there may have been a greater possibility for any degree of inhibition to show its influences on performance. On a task with over 95% accuracy of performance, a significant amount of inhibition would be required for any effects to emerge, and even then the task may simply be too easy for inhibition to have any deleterious effects. Note also that the phonological rhyme task was not a binary decision task (as is lexical decision), but rather multiple correct responses existed for a given cue and therefore chance performance was well below 50%. With chance performance being lower, again it may be that inhibition was more easily detectable on that task.

Consequences of Retrieval

In the conditional naming task (Experiment 2), significant facilitation effects were found for pictures previously named in English, providing evidence that the previous experience of naming pictures indeed had lasting, detectable effects on the subsequent processing of the L1 picture names. These facilitation effects were found when the L1 picture names appeared both as words and as pseudohomophones, which have been shown to be affected by phonological processes when making lexical decisions (e.g., Bentin, 1989; Pexman et al., 2001). That facilitation was found with both words and pseudohomophones is critical to the interpretation of the present set of results. Let us consider these two effects in turn.

L1 Picture Names

Naming pictures in the L1 necessarily involved specification and retrieval of the L1 phonological representation at study. It is likely, then, that phonological priming contributed to the facilitation effect for the words. Recent research has found that the orthographic representation may also be activated during speech production even in the absence of the orthographic form (e.g., Damian & Bowers, 2003; Hoshino, 2006), suggesting that orthographic priming could have also contributed to the facilitation effect for words. Given the overt requirement to specify the phonology during picture naming, it is likely that phonological priming contributed more to this facilitation effect than did orthographic priming, although the data from the word condition do not allow a direct test of this claim.

Pseudohomophones of L1 Picture Names

The contribution of phonological priming to the pseudohomophone facilitation effect is less clear. The pseudohomophone effect should have been exacerbated by the phonological processing at study. If the phonology was primed by the previous retrieval at study, then the match between the pseudohomophone's phonological representation and the base word's phonological representation should have become even more salient and therefore slowed correct rejections even more. However, it is possible, by means of a feedback mechanism, that the primed phonological representation activated its corresponding orthographic representation (see, e.g., Pexman et al., 2001, for evidence for this type of feedback in lexical decision), which was then submitted to a spelling check mechanism (e.g., Norris, 1984; Van Orden, 1987). That is, phonological priming may have, in fact, counterintuitively facilitated lexical decisions to pseudohomophones by feedback activation of the orthographic representation. This, together with any possible orthographic priming effects from retrieval at study (see above), may have therefore eliminated the standard pseudohomophone effect for this subset of items.

It is important to note that “new pseudohomophones” (i.e., pseudohomophones of pictures that had never appeared in the experiment) still showed the standard pseudohomophone effect relative to the non-word controls, demonstrating that the participants were still susceptible to the phonological influences of the pseudohomophones. The facilitation effect (and the elimination of the pseudohomophone effect) was restricted to the English naming condition, suggesting that it was the previous retrieval of the English picture name at study that caused this effect. This provides clear evidence that the pseudohomophone facilitation effect does not simply reflect a strategic shift in reliance on phonological processing. Rather, the current study provides evidence of orthographic and/or phonological priming as a consequence of naming pictures. Moreover, the presence of significant facilitation effects suggests that the lack of inhibitory effects from naming pictures in the L2 was not due to the paradigm being insensitive to the consequences of picture naming.

Implications for Models of Bilingual Speech Production

Evidence Against Inhibition

One could interpret the results of this study as evidence that L1 inhibition is not engaged during bilingual speech production. If the L1 phonology were inhibited during L2 picture naming (Levy et al., 2007), then inhibitory effects should have been found on the lexical decision task, particularly when the task engaged the same phonological processes (i.e., conditional word naming in Experiment 2). The facilitation effects reported in Experiments 1 and 2 not only contradict the claims of models that assume competition-for-selection (e.g., Green, 1998), but they also provide direct support for non-competition models by which activation in the non-target language does not impact language selection (e.g., Finkbeiner, Gollan et al., 2006). But note that for such a claim to hold, one must provide a non-inhibitory account both of L1 switch costs and of the fact that L1 picture naming latencies were longer in the mixed than in the blocked naming conditions.

Recently, Finkbeiner, Almeida et al. (2006) have argued that switch costs are not caused by linguistic inhibition but instead are driven by the bivalent nature of the stimuli typically used in these tasks. In a language switching experiment, stimuli (e.g., pictures, digits) are usually named in both languages, creating a situation where the stimuli are associated with two alternative responses. Mixed naming, therefore, creates response conflict, where two articulatory responses are sent to the output buffer and one must be selected for articulation. According to this valence account, larger switch costs for the L1 are an artifact of switching between easy and difficult tasks (i.e., naming in L1 vs.

naming in L2). On trials where the response criteria must be reestablished (i.e., on switch trials), responses that become available too quickly may be discarded or rejected simply by virtue of being available for output too soon. Thus, L1 (faster) names are rejected initially and then selected after the checking or decision mechanism determines what must be output. This delayed selection is the source of larger switch costs for the L1. That is, the response conflict occurs outside of the bilingual lexicon and therefore does not reflect cross-language competition during selection. By this account, without the need to reestablish the response criteria on non-switch trials, there should be no response conflict and therefore no slowing. But L1 naming latencies were in fact reliably slower on mixed naming non-switch trials relative to blocked naming, suggesting that L1 naming in the mixed condition incurred some additional processing cost. Thus, a purely non-inhibitory valence account fails to explain the full range of results reported here.

Evidence for inhibition

Alternatively, one must consider the possibility that inhibition was present at study but simply was not detected at test. There is a growing body of evidence from research on the neurocognition of bilingualism implicating inhibitory mechanisms in bilingual speech production (see, e.g., Abutalebi & Green, 2007). In the current study, there is some evidence from the L2 learners suggesting the L1 was being inhibited during the picture naming task. First, the switch cost asymmetry was present in both Experiments 1 and 2, with larger switch costs for the L1 than the L2 (although the asymmetry was only statistically significant in Experiment 2). Independent of the asymmetry, there were reliable switch costs in both languages in Experiments 1 and 2, which may itself serve as an independent marker of inhibition (e.g., Philipp et al., 2007). Finally, L1 naming latencies were reliably slower in the mixed naming condition than in the blocked naming condition. Taken together, these patterns in the picture naming data could be taken as evidence for L1 inhibition at study. It may be that some other procedural change made to the Levy et al. design masked or eliminated the inhibition in the current study. Given the number of modifications made to their original design in the present experiments, it is difficult to conclusively identify which factor(s) may have induced these changes.

As discussed above, the literature on language switching has focused almost exclusively on the asymmetry of the switch costs as an indicator of inhibition (e.g., Costa & Santesteban, 2004; Costa et al., 2006; Meuter & Allport, 1999). But it is important to note that asymmetric switch costs have not always been found with less proficient bilinguals, whose greater dominance in the L1 should make them likely to rely on inhibition (Green, 1998). For example, Christoffels, Firk and Schiller (2007) found symmetrical switch costs with unbalanced German-Dutch bilinguals during picture naming. However, naming latencies were slower in the L1 than in the L2 and a negative deflection in the frontal event-related potential (ERP) component (which has been linked to task switching and response suppression) was found in the L1 but not the L2, which taken together suggests the L1 was being inhibited. As discussed previously, Philipp et al. (2007) recently reported a dissociation between the switch cost asymmetry and the n-2 repetition cost – an independent measure of inhibition – suggesting that the presence or absence of an asymmetry may not be the best or sole indicator of inhibition. This suggestion is in line with recent calls in the literature on executive functioning to more precisely identify separable inhibitory functions (Miyake & Friedman, 2004).

Alternative Measures of Inhibition

Let us consider measures other than the switch cost asymmetry that may indicate the operation of an inhibitory mechanism. In the literature on task switching outside of the domain of language switching, some (e.g., Altmann, 2007) have argued that the switch cost source may be caused by the need to overcome lingering inhibition of the previously irrelevant but now relevant task set (i.e., schema of the procedures needed to perform the task). For example, when switching from word naming to color naming in the standard Stroop task, the procedures needed to name the textual word must be disengaged or even inhibited in order to allow the procedures for color naming to be selected and performed. Independent of the asymmetry, the switch cost itself can be taken as a measure of inhibition of the previous task's schema. Although other non-inhibitory mechanisms have been proposed (e.g., associative retrieval of task sets; Waszak, Hommel, & Allport, 2003), most task switching researchers have acknowledged that multiple mechanisms – including inhibition – are likely to be responsible for switch costs (Monsell, 2003).

It is a fair logical extension, then, to interpret language switch costs as reflecting the need to overcome lingering inhibition of the previously irrelevant 'task set' or language schema (e.g., Green, 1998; Meuter & Allport, 1999). However, to my knowledge, all language switching studies have based their conclusions on the nature of the switch costs asymmetry. In all three experiments involving mixed picture naming, significant switch costs were present in both languages. Indeed, an examination of the data from other language switching studies finds that significant switch costs are present in both languages, and this is true for both L2 learners and highly proficient bilinguals (Campbell, 2005; Christoffels et al., 2007; Costa & Santesteban, 2004; Costa et al., 2006; Meuter & Allport, 1999; Philipp et al., 2007; Jackson, Swainson, Cunnington, & Jackson, 2001). If switch costs reflect inhibitory mechanisms, then this would suggest that data from a number of published studies in fact provide additional evidence for inhibition during bilingual production. Note also that, in the analysis of individual differences (see *Chapter 7*), greater L1 and L2 switch costs both reliably predicted more facilitation on the lexical decision task at test, suggesting that the presence of inhibition had lasting consequences for the lexical representations of pictures named at study. Combined with the recent argument that the switch cost asymmetry may not be the best indicator of inhibition (Philipp et al.), these data suggest that future studies on language switching should consider the magnitude of the switch cost independent of the asymmetry as an indicator of inhibition.

It is also worth noting that in some cases production is slower in the L1 than in the L2, and this has been found with both unbalanced bilinguals (e.g., Campbell, 2005; Christoffels et al., 2007) and highly proficient bilinguals (Costa & Santesteban, 2004; Costa et al., 2006). This would suggest that the more dominant L1 was being inhibited during the switching task, allowing naming to occur more quickly in the relatively proficient but clearly less dominant L2. However, there is currently debate in the literature regarding whether inhibition can be found with more proficient bilinguals (see

Kroll et al., 2008, for a recent review). Let us now consider two alternative accounts that have been presented in the literature.

The Changing Role of Inhibition across L2 Proficiency

Costa and colleagues (e.g., Costa & Santesteban, 2004; Costa et al., 2006) have argued for a developmental shift in the reliance on inhibition. By their account, less proficient bilinguals may rely on inhibitory mechanisms to produce in the less dominant L2 in the face of the more dominant L1. But, with increasing proficiency in the L2, bilinguals then develop some attentional control skill that supports speech production in the L2 without the need for inhibition. Evidence in support of this account (see *The Language Specific Selection Mechanism Model* above) includes the results of a post-hoc analysis reported by Levy et al. (2007) suggesting that less proficient learners but not more proficient learners showed evidence of retrieval-induced forgetting (i.e., inhibition) on the phonological rhyme task at test. It is important to note, however, that Levy et al. specifically selected participants who were less proficient L2 learners. The null results from Experiment 4 of the current study are compatible with this account, although it is difficult to draw firm conclusions from these data given no evidence of inhibition was found in any of the other three experiments. Note that this account struggles to account for the finding that even highly proficient bilinguals have shown slower naming latencies in the L1 than in the L2 during language switching. Indeed, Costa and Santesteban briefly consider but then reject the hypothesis that this is due to the participants biasing towards preparing the less dominant L2 picture names in order to facilitate naming performance on L2 naming trials. To date, Costa and colleagues have failed to account for these results.

Others have argued that inhibition operates in bilinguals of all levels of proficiency (e.g., Abutalebi, 2008; Green, 1998; Kroll et al., 2008). Abutalebi and his colleagues (Abutalebi; Abutalebi & Green, 2007) have examined the neural pathways implicated in the control of bilingual speech production, and their findings are converging on the claim that frontal regions involved in conflict detection, conflict resolution and response suppression support language control via the up-regulation and down-regulation of the critical cortical and subcortical regions implicated in the language processing task at hand. For less proficient bilinguals, there appears to be a greater activation of the critical neural tissue (e.g., the dorsolateral prefrontal cortex, the anterior cingulate cortex and the caudate nucleus) when switching into the less dominant L2. ERP studies of language switching have also documented an asymmetry in activation of the frontal regions such that a negativity was found when switching into the more dominant L1 but not the less dominant L2, suggesting a greater need inhibition of the L1 during mixed naming (Jackson et al., 2001).

In the current study, both L2 learners and highly proficient bilinguals were tested in order to address these accounts of the role of inhibition at different levels of L2 proficiency. However, taken together, the results from the four experiments were mixed. In the picture naming task at study, there was clear evidence for inhibition with both participant groups showing significant switch costs. Moreover, L1 naming latencies were reliably slower in mixed naming than in blocked naming conditions. These results are in line with the claims of Green's (1998) Inhibitory Control model as well as recent claims from research on the neurocognition of bilingual speech production implicating inhibition as a functional mechanism to resolve cross-language competition (e.g., Abutalebi, 2008). However, the data on the asymmetry of switch costs was less robust, which would be taken by some as evidence against inhibition (e.g., Costa & Santesteban, 2004; Finkbeiner, Almeida et al., 2006). Moreover, in the lexical decision task at test, the predicted inhibitory effects were not detected for either participant group. Naming pictures in the L2 at study, if anything, facilitated lexical access to the L1 picture names at test.

Since the highly proficient Spanish-English bilinguals were living in and were tested in an English-dominant environment, it is possible that this group was comprised of a mix of Spanish-dominant and English-dominant bilinguals, which could have masked any underlying inhibitory effects. In order to test for this, the bilinguals were split into two groups based on their L1 and L2 self-rated proficiency: those who were clearly Spanish dominant (i.e., whose self-rated proficiency in Spanish was more than 1 point higher than their self-rated proficiency in English; n = 13), and those who were more balanced in proficiency or had become English dominant (i.e., whose self-rated Spanish proficiency was less than 1 point higher or was less than their self-rated proficiency in English; n = 10). Even when split by proficiency, both groups showed a switch cost asymmetry pattern in their picture naming data: the balanced bilinguals showed switch costs of 30 ms and 65 ms in English and Spanish, respectively, whereas the Spanish-dominant bilinguals showed switch costs of 50 ms and 85 ms in English and Spanish, respectively. Apparent language dominance per se (as reflected by self-rated proficiency) does not seem to determine the asymmetry of switch costs (cf. Costa & Santesteban, 2004). However, regardless of language dominance, these bilinguals did not show any evidence of inhibition on the lexical decision task at test. Naming pictures in Spanish had no real effect on lexical decisions to words (2 ms facilitation for balanced bilinguals vs. 3 ms interference for Spanish-dominant bilinguals). And for pseudohomophones, naming pictures in Spanish, if anything, facilitated lexical decisions (40 ms vs. 45 ms of facilitation for balanced bilinguals and Spanish-dominant bilinguals, respectively). Neither of these facilitation effects was statistically significant in the post-hoc analyses, $t(9) = 1.0$, $p > .20$ and $t(12) = 1.26$, $p > .20$, respectively. However, although the facilitation effects were not statistically significant in this analysis, the patterns suggest that picture naming has lasting effects on the accessibility of phonological representations even for highly proficient bilinguals. Combined with the significant effects reported in Experiment 2, these data would suggest that the inability to replicate the results of the study of Levy et al. (2007) was not due to an insensitivity of the paradigm to long term phonological effects.

The patterns of results from the lexical decision task are quite compatible with speech production models that assume that language non-selective activation does not create cross-language competition (e.g., Bloem et al., 2004; Costa et al., 2006; Finkbeiner, Gollan et al., 2006). According to these models, naming pictures in Spanish spreads activation to both the Spanish and the English picture name, and thus it should be easier to make lexical decisions to the English picture names at test regardless of the language of naming at study. Critically, the lexical decision results go against the predictions of the competition-for-selection model and the Inhibitory Control model. If naming pictures in Spanish at study requires inhibition of the non-target English picture name, then the English picture names should have required more time to overcome lingering inhibition at test. Should we, then, take these data as evidence against inhibition in bilingual speech production?

Even if we were to reject the inhibitory claims of Levy et al. (2007) based on the lexical decision data, given that the entire body of evidence on inhibition from both picture naming and lexical decision data in the current study is mixed and considering that the switch cost asymmetry may not be the clearest source of evidence of inhibition (e.g., Philipp et al., 2007; see also *Alternative Measures of Inhibition* above), it would be premature to altogether reject all inhibitory accounts of bilingual language selection. There is an accumulating body of evidence from a variety of tasks suggesting that being bilingual confers cognitive benefits to executive functioning skills, particularly in situations where competing irrelevant information must be inhibited or ignored to allow successful completion of the task (e.g., Bialystok et al., 2004; Bialystok & DePape, in press; Ransdell, Arecco, & Levy, 2001). These results have been found with bilinguals with a variety of language profiles, including children and aging adult bilinguals (Bialystok et al.), young adult early bilinguals (Costa et al., 2008) and young adult late bilinguals (Linck et al., under review). Yet some have argued that these positive effects of bilingualism do not lead to gains in inhibitory control but rather to an enhanced ability to control attention via the maintenance of goal-relevant information (e.g., Colzato et al., 2008), a view that is congruent with the claims of some non-competition models (see *Models of Bilingual Language Selection*). Such an account would lead to the prediction that bilinguals should also show larger benefits from non-conflict conditions in which cues can be exploited to facilitate performance. Recently, however, Costa et al. (2008)

failed to find a bilingual advantage in the control of attention within such non-conflict conditions. Despite finding clear bilingual benefits in conditions requiring the resolution of competition among alternative responses, bilinguals and monolinguals were similarly able to exploit an exogenous cue to control attention. Similarly, Bialystok (2006) reported bilingual benefits in young adults who performed a variant of the Simon task, but this benefit was restricted to high conflict conditions. That reliable differences are not found in congruent conditions when information could be exploited to facilitate attentional control in the absence of conflict suggests that being bilingual specifically improves the ability to guide attention in the face of conflicting information.

In the data reported to date, however, the link between bilingualism and cognitive advantages (e.g., enhanced executive functioning) has only been correlational in nature. No direct evidence of a causal relationship has been provided thus far. This is an important issue to bear in mind, and one that deserves more attention in the literature. Much of the discussion in the literature has suggested a causal relationship, with the need for competition resolution inducing long-lasting changes in bilinguals' executive functioning and inhibitory control abilities. It will be important for future work to examine this question longitudinally in order to more directly and explicitly test the hypothesis that the bilingual experience is in fact a causal mechanism driving these bilingual advantages. Two potentially informative populations that merit consideration for such longitudinal investigations have already been identified in the literature, namely immersion learners and professional interpreters.

Linck et al. (in preparation) recently reported preliminary evidence that the L2 immersion environment is one context that may facilitate the development of L1 inhibition skills, but note that their study was cross-sectional in design and therefore relied upon between-subjects comparisons. Given that L2 proficiency gains have been observed to occur in a relatively short time within the L2 immersion context (e.g., Freed, Segalowitz, & Dewey, 2004; Segalowitz & Freed, 2004; Taguchi, 2008), this context seems ripe for longitudinal studies of immersion learners before, during and after the immersion experience to examine learners who are at an intermediate level of L2 proficiency. In order to provide data on more proficient bilinguals, another key bilingual population is professional interpreters. Christoffels, De Groot and Kroll (2006) found that professional interpreters had greater working memory resources than highly proficient bilinguals who were not trained as interpreters, but again the comparisons were made between subjects and thus cannot conclusively define the causal link. In both cases, by examining within each individual the changes in executive functioning and inhibitory control that may occur between the beginning and end of the target learning period (i.e., the immersion experience or professional interpreter training), such longitudinal studies would allow a direct test of the causal link between bilingualism and cognitive consequences. Clearly this line of work requires the commitment of many resources across a long period of time and is susceptible to the loss of data through participant attrition, but research of this nature would allow more definitive conclusions to be drawn and would support advances in theoretical models relating cognition and bilingualism.

Note also that the discussion thus far has focused on the impact of conflict resolution at the lexical level of processing. However, one must also consider other levels of language processing that may contribute to these cognitive benefits. For example, recent research suggests that conflicting parsing preferences for L1 and L2 translation equivalents can impact online syntactic processing in a monolingual context (e.g., Dussias & Cramer Scaltz, 2007; Dussias & Sagarra, 2007). The presence of this conflicting syntactic information may therefore create an additional need for conflict resolution skills. This need may be particularly pressing in the case of bilingual code-switching, where an intrasentential code-switch may occur at a point where the syntactic structure conflicts across the bilingual's two languages (e.g., De Bot & Schreuder, 1993). It is possible that the bilingual cognitive advantages are caused by this need for conflict resolution at the syntactic level but not the lexical level of processing. It will be important for future studies to examine the relative contribution to bilingual cognitive benefits of competition resolution at these various levels of representation.

Comments on the Nature of Inhibition

In the data from the present study, the two measures of inhibition included in the design operated independently: participants suffered reliable language switch costs on the picture naming task at study but showed no inhibitory effects on the lexical decision task at test. If language switch costs serve as evidence of global inhibition (e.g., Green, 1998; Meuter & Allport, 1999), and if the predicted cross-language retrieval induced forgetting effect reflects local inhibition of the representation that operates during retrieval (e.g., Anderson & Spellman, 1995; Levy et al., 2007), then the present data are congruent with an account by which global and local inhibitory mechanisms are argued to operate independently. With recent calls in the literature to begin making clearer distinctions among separable inhibitory processes (e.g., Friedman & Miyake, 2004), the present study took a key step in making such empirical and theoretical distinctions between inhibitory mechanisms in bilingual language processing. Since facilitation rather than inhibition effects were found in the present study, data are needed from studies examining the relationship between global and local inhibition under conditions where evidence of both inhibitory mechanisms is found before definitive conclusions can be made regarding their functional independence.

One potentially informative line of research could be to examine the neural regions implicated in cross-language retrieval induced forgetting. Research on the neural mechanisms supporting bilingual language production has implicated a specific network of brain areas in language control (see Abutalebi & Green, 2007, for a recent review). Specifically, it is postulated that the left basal ganglia and anterior cingulate cortex (ACC) signal the need for control by modulating activation in the dorsolateral prefrontal cortex (DLPFC), which then implements such control by modulating the posterior regions involved in the current task. This converges nicely with recent developments in the memory literature, where the ACC and DLPFC have also been implicated as neural mechanisms responsible for the control of memory retrieval in part through active suppression (i.e., inhibition) of competing, unwanted memories (e.g., Levy & Anderson, 2002). Taken together, these lines of work might lead to speculation regarding the brain areas involved in the specific case of language control – cross-language retrieval induced forgetting – investigated in this study. If the L1 is inhibited during L2 picture naming at study, then the degree to which the above brain areas are activated might be expected to predict the magnitude of cross-language retrieval induced forgetting at test. That is, greater activation of the ACC and DLPFC on L2 naming trials should predict slower and/or less accurate lexical decisions to the L1 names of pictures previously named in the L2.

In a recent discussion on the nature of inhibition, Colzato et al. (2008) argued for a clearer distinction between *active* and *reactive inhibition* with a more precise explanation of the origin of such inhibitory mechanisms. According to their view, representations can be inhibited actively by some top-down inhibitory control mechanism external to the language system, similar to Green's (1998) Inhibitory Control model, but they can also be inhibited reactively through lateral inhibitory links between related representations, as has been instantiated in the Bilingual Interactive Activation model of word recognition (Dijkstra & Van Heuven, 2002). Note that the term reactive inhibition here specifies the origin of inhibition as being via lateral connections, whereas within the Inhibitory Control model reactive inhibition specifies the temporal functioning of the inhibition (i.e., as a response to activation of non-target representations). As advances are made in our theoretical models of these inhibitory mechanisms, more precise specification is needed with respect to their functional properties. Clearer theoretical commitments will allow more specific, testable predictions to be made in order to identify the conditions in which inhibitory mechanisms support bilingual language processing. For example, with respect to the current study, one could argue that Levy et al.'s (2007) effects were likely driven by (reactive) lateral inhibition between the competing lexical representations in the two languages. We would then predict that these effects should be accounted for by individual differences in lateral inhibition but not by individual differences in active, top-down inhibitory control. Although we can neither confirm nor reject the former prediction based on the current data, the latter prediction was supported in that retrieval induced forgetting was unrelated to the Simon effect, which has been argued to serve as a non-linguistic measure of inhibitory control (e.g., Linck et al., under review; but see Bialystok, 2006, for a discussion of variants of the Simon task that my better tap into active inhibitory mechanisms). It will be important for future research to more precisely discriminate among various inhibitory mechanisms empirically in order to advance a more nuanced conceptualization of inhibitory processes.

Further analysis of individual differences in language and cognitive processes as well as their underlying neural mechanisms will provide important data to further our understanding of the complex interrelationships that may or may not exist between these processes. There is a clear need for a well articulated, principled account of how cognitive control mechanisms function with respect to bilingual language processing. This is a ripe area for both theoretical and empirical work as our field develops a more sophisticated understanding of executive functioning per se as well as its important role in bilingual language processing. Indeed, while recent work (e.g,. Friedman & Miyake, 2004) has begun to differentiate various facets of executive functioning (e.g., inhibition), it is apparent that more fine-grained dissociations within such general functions are needed to better understand their functional roles in supporting cognition more broadly (e.g,. Fournier-Vicente, Larigauderie, & Gaonac'h, 2008). Similar work is needed to generate a principled account of how these fine-grained executive functions contribute to the various processes involved in bilingual language use.

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Appendix A

Language History Questionnaire

Note: The following questions were administered electronically using Microsoft Access.

Please indicate the following:

Gender

Age

Handedness

Where were you born?

On a scale from 1 (not proficient) to 10 (native-like), please rate your:

English reading proficiency

English writing proficiency

English speaking ability

English speech comprehension

Spanish reading proficiency

Spanish writing proficiency

Spanish speaking ability

Spanish speech comprehension

For how many years have you spoken your second language?

How often, and where, do you use your second language?

Have you ever studied or lived abroad? If so, where and for how long?

What other languages have you been exposed to? Please try to be as specific as possible as to your level of proficiency, years of exposure, etc.

Do you have any health concerns, including fatigue and corrected vision or hearing, that may have affected your participation today?

Have you participated in other language experiments? If so, please describe the previous experiment(s).

Appendix B

Critical Picture Stimuli used in Picture Naming Task

Picture	Spanish Name	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Age of Acquisition [a]	Image-ability [a]	Familiarity [a]	Lexical Decision RT (ms) [b]	Word Naming RT (ms) [b]
axe	hacha	3	0.82	8	311	597	461	662	605
bag	bolsa	3	1.8	22	217	570	634	593	525
banana	plátano, banana	6	0.71	0	193	644	576	633	643
basket	cesta	6	1.28	2	-	560	485	650	584
bear	oso	4	1.85	18	220	572	526	566	584
beard	barba	5	1.37	3	260	631	480	575	671
bed	cama	3	2.39	14	169	635	636	557	555
bell	campana	4	1.61	13	241	566	495	561	600
belt	cinturón	4	1.35	10	268	585	577	596	576
bird	pájaro	4	1.63	4	206	614	592	596	588
boat	barco	4	1.75	9	-	631	584	550	617
bone	hueso	4	1.45	15	261	625	525	656	592
boot	bota	4	1.03	17	251	604	566	531	630

Picture	Spanish Name	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Age of Acquisition [a]	Image-ability [a]	Familiarity [a]	Lexical Decision RT (ms) [b]	Word Naming RT (ms) [b]
bottle	botella	6	1.92	1	-	619	591	607	558
boy	chico, muchacho	3	2.34	14	150	618	606	533	556
bread	pan	5	1.88	6	183	650	636	590	600
brush	cepillo	5	1.28	3	214	570	579	639	558
butterfly	mariposa	9	0.77	0	-	624	481	635	620
button	botón	6	1.25	2	192	580	573	598	573
cake	torta	4	1.35	18	214	624	594	564	664
candle	vela	6	0.95	1	-	594	544	581	625
car	coche	3	2.44	18	197	638	634	642	634
castle	castillo	6	1.78	1	-	-	-	615	609
cat	gato	3	1.63	22	-	617	582	521	600
chain	cadena	5	1.53	1	311	559	513	552	652
chair	silla	5	2.02	2	-	610	617	607	607
cheese	queso	6	1.46	0	211	592	588	579	688
cherry	cereza	6	0.84	2	317	582	514	573	659
chicken	pollo	7	1.5	1	250	619	544	575	686

Picture	Spanish Name	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Age of Acquisition [a]	Image-ability [a]	Familiarity [a]	Lexical Decision RT (ms) [b]	Word Naming RT (ms) [b]
church	iglesia	6	2.2	0	278	616	560	612	602
clock	reloj	5	1.56	7	210	640	636	584	581
cloud	nube	5	1.51	2	223	624	558	577	615
coat	abrigo	4	1.73	9	197	572	610	688	562
cookie	galleta	6	0.43	3	-	600	585	577	579
cow	vaca	3	1.37	23	174	632	529	581	573
crown	corona	5	1.41	7	245	645	447	627	589
cup	copa	3	1.79	9	-	558	595	618	548
dog	perro	3	1.86	14	169	636	598	556	562
doll	muñeca	4	1.27	11	161	565	503	616	562
donkey	burro	6	1	1	235	631	-	648	610
door	puerta	4	2.52	6	214	599	630	507	591
dress	vestido	5	1.93	5	227	661	592	550	584
drum	tambor	4	0.99	2	319	599	506	605	652
duck	pato	4	1.08	13	164	632	529	546	573
egg	huevo	3	1.58	1	186	599	608	565	585

Picture	Spanish Name	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Age of Acquisition [a]	Image-ability [a]	Familiarity [a]	Lexical Decision RT (ms) [b]	Word Naming RT (ms) [b]
envelope	sobre	8	1.3	0	-	554	542	663	664
faucet	grifo	6	0.39	0	643	356	386	663	660
finger	dedo	6	1.7	6	178	648	621	642	626
fire	fuego	4	2.19	15	189	634	580	545	636
fish	pez, pescado	4	2.24	3	275	615	548	575	579
flag	bandera	4	1.32	8	258	607	545	534	611
floor	suelo	5	2.21	2	204	544	551	563	603
flower	flor	6	1.46	4	166	618	566	603	618
fork	tenedor	4	1.17	8	225	598	584	650	631
fox	zorro	3	1.17	8	283	607	501	605	586
frog	rana	4	0.73	3	258	617	507	608	580
girl	chica, muchacha	4	2.44	3	183	634	645	556	571
glass	vaso	5	2.1	3	284	585	611	573	590
grapes	uvas	6	0.95	9	-	-	-	591	613
gun	pistola	3	1.81	14	228	613	519	578	614
hat	sombrero, gorro	3	1.73	22	-	562	580	577	633

Picture	Spanish Name	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Age of Acquisition [a]	Image-ability [a]	Familiarity [a]	Lexical Decision RT (ms) [b]	Word Naming RT (ms) [b]
heart	corazón	5	2.16	2	281	617	578	573	580
horse	caballo	5	1.93	5	239	624	560	626	573
house	casa	5	2.75	5	189	606	600	494	573
key	llave	3	1.86	5	-	618	603	544	571
king	rey	4	1.96	9	277	585	522	559	600
knife	cuchillo	5	1.58	0	245	636	610	590	589
leaf	hoja	4	1.22	7	225	655	540	559	561
lettuce	lechuga	7	0.87	0	276	635	558	632	644
lobster	langosta	7	0.48	0	-	630	472	596	639
man	hombre	3	3.03	19	176	567	623	513	579
monkey	mono	6	1	1	269	588	531	612	550
moon	luna	4	1.73	10	204	648	513	614	573
mouse	ratón	5	0.96	6	242	615	520	623	587
mushroom	champiñón	8	0.78	0	-	-	-	641	575
necklace	collar	8	0.52	0	-	606	536	731	604
net	red	3	1.52	16	269	540	514	596	558

Picture	Spanish Name	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Age of Acquisition [a]	Image-ability [a]	Familiarity [a]	Lexical Decision RT (ms) [b]	Word Naming RT (ms) [b]
nose	nariz	4	1.87	10	206	605	584	572	597
nurse	enfermera	5	1.53	2	261	654	509	541	580
octopus	polpo	7	0.39	0	-	-	-	760	659
onion	cebolla	5	1.02	1	286	617	550	676	629
orange	naranja	6	1.48	1	203	626	567	608	544
paper	papel	5	2.24	6	229	590	635	623	529
pencil	lápiz	6	1.22	0	225	607	598	640	609
pig	cerdo	3	1.28	14	233	635	509	583	570
pineapple	piña	9	0.54	0	-	569	489	743	652
plug	enchufe	4	0.92	3	242	583	575	609	569
pool	piscina	4	1.55	9	239	577	541	581	575
present	regalo	7	2.39	1	221	481	569	654	681
queen	reina	5	1.7	1	247	612	527	565	593
rabbit	conejo	6	1.07	1	206	611	523	590	556
rain	lluvia	4	1.86	10	211	618	604	552	584
rope	cuerda	4	1.51	15	281	596	539	567	534

Picture	Spanish Name	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Age of Acquisition [a]	Image-ability [a]	Familiarity [a]	Lexical Decision RT (ms) [b]	Word Naming RT (ms) [b]
ruler	regla	5	0.94	3	311	543	571	631	596
scissors	tijeras	8	0.73	0	-	609	559	698	682
sheep	oveja	5	1.61	6	199	641	484	563	625
shirt	camisa	5	1.67	4	269	612	612	595	647
shoe	zapato	4	1.19	6	152	640	635	637	657
shoulder	hombro	8	1.84	0	264	577	553	628	660
skirt	falda	5	1.34	1	258	573	551	650	680
smoke	humo	5	1.77	4	228	615	596	609	615
spider	araña	6	0.71	0	254	597	526	625	644
spoon	cuchara	5	1.14	4	186	584	612	575	630
stairs	escaleras	6	1.67	1	245	-	-	556	640
strawberry	fresa	10	0.58	0	-	-	-	783	684
suitcase	maleta	8	1.12	0	-	-	-	720	735
sun	sol	3	2.19	14	181	639	635	551	612
sword	espada	5	1.15	3	342	597	444	571	680
table	mesa	5	2.31	4	185	582	599	665	600

Picture	Spanish Name	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Age of Acquisition [a]	Image-ability [a]	Familiarity [a]	Lexical Decision RT (ms) [b]	Word Naming RT (ms) [b]
tape	cinta	4	1.47	10	406	573	567	622	605
teeth	dientes	5	1.9	1	198	636	588	550	616
toilet	baño	6	1.38	1	164	632	666	631	580
trash	basura	5	0.67	2	-	599	541	594	583
tree	árbol	4	1.86	4	171	644	565	587	631
truck	camión	5	1.41	4	261	590	484	567	615
turtle	tortuga	6	0.5	1	-	564	509	672	637
wheel	rueda	5	1.48	0	214	622	530	563	600
window	ventana	6	2.13	0	231	602	621	641	600
woman	mujer	5	2.53	2	258	626	623	546	581
wood	madera	4	1.87	8	269	577	574	595	580

Note. RT = reaction time.

[a] Data were compiled using the N-Watch program (Davis, 2005). [b] Normed data available through the English Lexicon Project (Balota et al., 2007).

Appendix C

Words and Non-words Used in Lexical Decision Task

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
axe	Critical Item	acks	3	0.82	8	662	97	605	96
bag	Critical Item	baggh	3	1.8	22	593	100	525	100
banana	Critical Item	benanna	6	0.71	0	633	100	643	100
basket	Critical Item	basquet	6	1.28	2	650	100	584	100
bear	Critical Item	bair	4	1.85	18	566	100	584	92.9
beard	Critical Item	beerde	5	1.37	3	575	91	671	92.9
bed	Critical Item	behd	3	2.39	14	557	97	555	100
bell	Critical Item	behl	4	1.61	13	561	100	600	100
belt	Critical Item	bellte	4	1.35	10	596	100	576	100
bird	Critical Item	berd	4	1.63	4	596	97	588	100
boat	Critical Item	bote	4	1.75	9	550	100	617	100
bone	Critical Item	boan	4	1.45	15	656	97	592	96.4
boot	Critical Item	bootte	4	1.03	17	531	97	630	100

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
bottle	Critical Item	boddle	6	1.92	1	607	100.0	558	100.0
boy	Critical Item	boi	3	2.34	14	533	97.0	556	100.0
bread	Critical Item	bredde	5	1.88	6	590	100.0	600	100.0
brush	Critical Item	brusch	5	1.28	3	639	100.0	558	100.0
butterfly	Critical Item	budderflie	9	0.77	0	635	94.0	620	100.0
button	Critical Item	butinn	6	1.25	2	598	94.0	573	100.0
cake	Critical Item	cayk	4	1.35	18	564	100.0	664	100.0
candle	Critical Item	kandul	6	0.95	1	581	100.0	625	100.0
car	Critical Item	karr	3	2.44	18	642	94.0	634	100.0
castle	Critical Item	kassle	6	1.78	1	615	97.0	609	100.0
cat	Critical Item	katt	3	1.63	22	521	94.0	600	100.0
chain	Critical Item	chayn	5	1.53	1	552	100.0	652	100.0
chair	Critical Item	chare	5	2.02	2	607	97.0	607	100.0
cheese	Critical Item	cheze	6	1.46	0	579	97.0	688	100.0
cherry	Critical Item	chairrey	6	0.84	2	573	100.0	659	92.3

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
chicken	Critical Item	chikin	7	1.5	1	575	100.0	686	100.0
church	Critical Item	chertch	6	2.2	0	612	97.0	602	100.0
clock	Critical Item	klok	5	1.56	7	584	97.0	581	96.4
cloud	Critical Item	klowd	5	1.51	2	577	100.0	615	100.0
coat	Critical Item	kote	4	1.73	9	688	94.0	562	100.0
cookie	Critical Item	cookey	6	0.43	3	577	97.0	579	100.0
cow	Critical Item	koww	3	1.37	23	581	94.0	573	100.0
crown	Critical Item	krounn	5	1.41	7	627	100.0	589	100.0
cup	Critical Item	kupp	3	1.79	9	618	97.0	548	100.0
dog	Critical Item	dawg	3	1.86	14	556	97.0	562	100.0
doll	Critical Item	daul	4	1.27	11	616	100.0	562	100.0
donkey	Critical Item	dawnkee	6	1	1	648	97.0	610	100.0
door	Critical Item	dore	4	2.52	6	507	97.0	591	96.3
dress	Critical Item	jress	5	1.93	5	550	100.0	584	96.4
drum	Critical Item	druhmm	4	0.99	2	605	100.0	652	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
duck	Critical Item	dukh	4	1.08	13	546	100.0	573	100.0
egg	Critical Item	egh	3	1.58	1	565	100.0	585	100.0
envelope	Critical Item	ennviloap	8	1.3	0	663	100.0	664	96.4
faucet	Critical Item	fossit	6	0.39	0	663	97.0	660	96.3
finger	Critical Item	phingre	6	1.7	6	642	100.0	626	100.0
fire	Critical Item	fyer	4	2.19	15	545	100.0	636	100.0
fish	Critical Item	phisch	4	2.24	3	575	91.0	579	100.0
flag	Critical Item	phlagg	4	1.32	8	534	97.0	611	100.0
floor	Critical Item	flore	5	2.21	2	563	97.0	603	100.0
flower	Critical Item	flauer	6	1.46	4	603	100.0	618	96.3
fork	Critical Item	forque	4	1.17	8	650	100.0	631	100.0
fox	Critical Item	focks	3	1.17	8	605	97.0	586	100.0
frog	Critical Item	frawgg	4	0.73	3	608	97.0	580	100.0
girl	Critical Item	gurrl	4	2.44	3	556	97.0	571	100.0
glass	Critical Item	ghlas	5	2.1	3	573	97.0	590	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
grapes	Critical Item	graips	6	0.95	9	591	100.0	613	100.0
gun	Critical Item	gunne	3	1.81	14	578	97.0	614	100.0
hat	Critical Item	hatte	3	1.73	22	577	100.0	633	100.0
heart	Critical Item	harte	5	2.16	2	573	97.0	580	100.0
horse	Critical Item	hoorce	5	1.93	5	626	100.0	573	100.0
house	Critical Item	howsse	5	2.75	5	494	100.0	573	100.0
key	Critical Item	kee	3	1.86	5	544	97.0	571	100.0
king	Critical Item	khing	4	1.96	9	559	97.0	600	100.0
knife	Critical Item	nyfe	5	1.58	0	590	97.0	589	100.0
leaf	Critical Item	leef	4	1.22	7	559	94.0	561	100.0
lettuce	Critical Item	lettis	7	0.87	0	632	100.0	644	92.9
lobster	Critical Item	lobbstir	7	0.48	0	596	97.0	639	100.0
man	Critical Item	manne	3	3.03	19	513	97.0	579	100.0
monkey	Critical Item	munkee	6	1	1	612	100.0	550	100.0
moon	Critical Item	mune	4	1.73	10	614	100.0	573	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
mouse	Critical Item	mowse	5	0.96	6	623	94.0	587	100.0
mushroom	Critical Item	muschrume	8	0.78	0	641	97.0	575	100.0
necklace	Critical Item	nekliss	8	0.52	0	731	88.0	604	100.0
net	Critical Item	knett	3	1.52	16	596	97.0	558	100.0
nose	Critical Item	knoes	4	1.87	10	572	100.0	597	100.0
nurse	Critical Item	nerse	5	1.53	2	541	91.0	580	100.0
octopus	Critical Item	awktipuss	7	0.39	0	760	97.0	659	100.0
onion	Critical Item	unyin	5	1.02	1	676	100.0	629	100.0
orange	Critical Item	orrinj	6	1.48	1	608	97.0	544	100.0
paper	Critical Item	paypir	5	2.24	6	623	97.0	529	100.0
pencil	Critical Item	pennsul	6	1.22	0	640	97.0	609	100.0
pig	Critical Item	piggh	3	1.28	14	583	94.0	570	100.0
pineapple	Critical Item	pynappull	9	0.54	0	743	91.0	652	100.0
plug	Critical Item	pluhgg	4	0.92	3	609	100.0	569	100.0
pool	Critical Item	poohle	4	1.55	9	581	100.0	575	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
present	Critical Item	prezzint	7	2.39	1	654	97.0	681	100.0
queen	Critical Item	kween	5	1.7	1	565	97.0	593	100.0
rabbit	Critical Item	rabett	6	1.07	1	590	100.0	556	100.0
rain	Critical Item	rayne	4	1.86	10	552	100.0	584	100.0
rope	Critical Item	roap	4	1.51	15	567	97.0	534	100.0
ruler	Critical Item	rooler	5	0.94	3	631	97.0	596	100.0
scissors	Critical Item	sizzers	8	0.73	0	698	100.0	682	100.0
sheep	Critical Item	shepe	5	1.61	6	563	94.0	625	100.0
shirt	Critical Item	sherrt	5	1.67	4	595	100.0	647	96.4
shoe	Critical Item	sheww	4	1.19	6	637	97.0	657	100.0
shoulder	Critical Item	shoaldur	8	1.84	0	628	94.0	660	100.0
skirt	Critical Item	skert	5	1.34	1	650	94.0	680	100.0
smoke	Critical Item	smoque	5	1.77	4	609	100.0	615	100.0
spider	Critical Item	spyter	6	0.71	0	625	97.0	644	100.0
spoon	Critical Item	spune	5	1.14	4	575	100.0	630	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
stairs	Critical Item	staerz	6	1.67	1	556	94.0	640	100.0
strawberry	Critical Item	strahbearie	10	0.58	0	783	100.0	684	100.0
suitcase	Critical Item	sutekace	8	1.12	0	720	88.0	735	100.0
sun	Critical Item	sunnh	3	2.19	14	551	97.0	612	100.0
sword	Critical Item	sorde	5	1.15	3	571	97.0	680	96.4
table	Critical Item	tabel	5	2.31	4	665	100.0	600	100.0
tape	Critical Item	tayp	4	1.47	10	622	100.0	605	100.0
teeth	Critical Item	teath	5	1.9	1	550	97.0	616	100.0
toilet	Critical Item	toylit	6	1.38	1	631	100.0	580	100.0
trash	Critical Item	chrash	5	0.67	2	594	97.0	583	100.0
tree	Critical Item	chree	4	1.86	4	587	97.0	631	100.0
truck	Critical Item	truque	5	1.41	4	567	100.0	615	100.0
turtle	Critical Item	tertel	6	0.5	1	672	97.0	637	100.0
wheel	Critical Item	weal	5	1.48	0	563	97.0	600	100.0
window	Critical Item	wyndowe	6	2.13	0	641	94.0	600	96.4

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
woman	Critical Item	woomin	5	2.53	2	546	100.0	581	100.0
wood	Critical Item	whould	4	1.87	8	595	94.0	580	100.0
air	Control Word		3	2.41	5	590	100.0	588	100.0
album	Control Word		5	0.78	0	581	94.0	585	100.0
any	Control Word		3	3.13	4	647	94.0	590	92.6
apricot	Control Word		7	0.00	0	734	97.0	665	100.0
award	Control Word		5	1.66	1	673	97.0	591	100.0
ball	Control Word		4	2.04	19	644	94.0	570	100.0
bar	Control Word		3	1.91	15	573	97.0	580	100.0
beaver	Control Word		6	0.48	5	637	97.0	661	100.0
bee	Control Word		3	1.04	11	576	100.0	602	100.0
beef	Control Word		4	1.51	6	591	97.0	606	100.0
beer	Control Word		4	1.53	12	587	100.0	574	96.4
bishop	Control Word		6	1.26	0	589	88.0	621	100.0
bomb	Control Word		4	1.56	4	602	97.0	578	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
brain	Control Word		5	1.65	6	584	100.0	594	100.0
bubble	Control Word		6	1.08	4	619	100.0	582	96.3
bucket	Control Word		6	0.85	2	595	97.0	653	100.0
bull	Control Word		4	1.15	15	584	97.0	570	100.0
bus	Control Word		3	1.53	8	567	97.0	579	100.0
cable	Control Word		5	0.85	6	585	100.0	608	100.0
camera	Control Word		6	1.56	0	632	100.0	599	100.0
cap	Control Word		3	1.43	18	597	97.0	554	100.0
carpet	Control Word		6	1.11	0	645	97.0	604	96.2
case	Control Word		4	2.56	14	543	97.0	634	100.0
catfish	Control Word		7	0.30	0	602	97.0	635	100.0
center	Control Word		6	2.35	1	561	100.0	580	100.0
cheek	Control Word		5	1.30	4	642	97.0	653	92.0
child	Control Word		5	2.33	3	622	94.0	589	100.0
children	Control Word		8	2.55	0	637	100.0	613	96.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
coach	Control Word		5	1.38	4	611	100.0	602	92.9
coffee	Control Word		6	1.89	2	588	97.0	587	100.0
color	Control Word		5	2.15	1	568	100.0	565	100.0
corridor	Control Word		8	1.23	0	694	85.0	689	92.9
country	Control Word		7	2.51	0	633	100.0	630	100.0
crash	Control Word		5	1.30	5	639	100.0	597	100.0
deer	Control Word		4	1.11	11	581	100.0	633	100.0
dinosaur	Control Word		8	0.00	0	723	88.0	638	96.3
dwarf	Control Word		5	0.48	0	644	100.0	597	100.0
earrings	Control Word		8	0.48	1	689	100.0	616	100.0
eight	Control Word		5	2.02	7	580	94.0	611	100.0
eraser	Control Word		6	0.30	1	659	94.0	663	100.0
fountain	Control Word		8	1.26	1	629	97.0	648	100.0
game	Control Word		4	2.09	13	579	97.0	567	100.0
garden	Control Word		6	1.78	2	579	100.0	577	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
gas	Control Word		3	1.99	8	550	100.0	572	100.0
gift	Control Word		4	1.52	7	641	100.0	591	100.0
god	Control Word		3	2.50	9	638	91.0	597	100.0
grass	Control Word		5	1.72	8	563	100.0	614	100.0
guy	Control Word		3	1.71	6	588	100.0	571	100.0
heels	Control Word		5	1.36	7	597	97.0	617	100.0
hiking	Control Word		6	0.30	4	611	97.0	570	100.0
hole	Control Word		4	1.76	13	562	94.0	578	100.0
ink	Control Word		3	0.85	3	575	100.0	592	100.0
jug	Control Word		3	0.78	10	655	97.0	602	100.0
jury	Control Word		4	1.83	4	571	100.0	631	100.0
lake	Control Word		4	1.73	16	590	100.0	531	100.0
land	Control Word		4	2.34	11	594	97.0	566	100.0
lemon	Control Word		5	1.26	1	542	100.0	588	100.0
letters	Control Word		7	2.06	2	640	100.0	585	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
lime	Control Word		4	1.11	13	596	100.0	557	100.0
lion	Control Word		4	1.23	4	531	97.0	572	100.0
lotion	Control Word		6	0.90	3	633	94.0	638	96.4
lung	Control Word		4	1.20	5	646	94.0	617	100.0
mailbox	Control Word		7	0.00	0	639	97.0	596	100.0
metal	Control Word		5	1.79	2	585	97.0	595	100.0
mice	Control Word		4	1.00	13	594	91.0	567	100.0
mirror	Control Word		6	1.43	0	560	100.0	571	100.0
motor	Control Word		5	1.75	1	579	100.0	620	100.0
nightclub	Control Word		9	0.30	0	645	97.0	613	100.0
oil	Control Word		3	1.97	3	604	100.0	580	100.0
palm	Control Word		4	1.34	5	618	94.0	589	100.0
park	Control Word		4	1.97	11	616	100.0	559	100.0
parrot	Control Word		6	0.00	1	697	100.0	611	100.0
patch	Control Word		5	1.11	10	534	100.0	602	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
pepper	Control Word		6	1.11	2	661	97.0	615	100.0
piano	Control Word		5	1.58	0	561	97.0	611	100.0
pie	Control Word		3	1.15	10	582	97.0	590	100.0
pilot	Control Word		5	1.64	1	574	100.0	588	100.0
pizza	Control Word		5	0.48	0	559	97.0	611	100.0
plant	Control Word		5	2.10	4	577	97.0	595	100.0
platform	Control Word		8	1.86	0	659	97.0	628	100.0
pole	Control Word		4	1.26	14	577	100.0	606	100.0
radio	Control Word		5	2.08	2	599	97.0	615	100.0
ranch	Control Word		5	1.43	0	579	97.0	604	100.0
right	Control Word		5	2.79	7	586	97.0	567	100.0
river	Control Word		5	2.22	7	606	100.0	600	100.0
saxophone	Control Word		9	0.60	0	793	97.0	678	100.0
scout	Control Word		5	0.90	7	659	100.0	627	100.0
shell	Control Word		5	1.34	6	606	97.0	627	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
ship	Control Word		4	1.92	8	558	100.0	645	100.0
shop	Control Word		4	1.80	9	611	100.0	573	100.0
silk	Control Word		4	1.08	8	634	97.0	615	100.0
sky	Control Word		3	1.76	7	523	97.0	635	100.0
soap	Control Word		4	1.34	6	574	100.0	619	100.0
solid	Control Word		5	1.89	0	616	94.0	613	100.0
star	Control Word		4	1.40	10	524	97.0	590	100.0
stomach	Control Word		7	1.57	0	584	91.0	671	100.0
storm	Control Word		5	1.41	3	597	100.0	639	100.0
straw	Control Word		5	1.18	3	663	100.0	649	100.0
tax	Control Word		3	2.29	13	595	97.0	595	100.0
throat	Control Word		6	1.71	1	602	97.0	603	100.0
tiger	Control Word		5	0.85	4	596	97.0	669	88.5
tissue	Control Word		6	1.61	0	634	100.0	603	100.0
tomato	Control Word		6	0.60	0	640	97.0	656	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
tomb	Control Word		4	1.04	4	599	91.0	657	95.8
town	Control Word		4	2.33	4	603	94.0	587	100.0
trophy	Control Word		6	0.90	0	664	97.0	631	100.0
tube	Control Word		4	1.49	4	590	100.0	606	96.3
tunnel	Control Word		6	1.00	1	563	94.0	648	100.0
turkey	Control Word		6	0.95	0	584	100.0	598	96.4
union	Control Word		5	2.26	2	622	100.0	616	91.7
vegetable	Control Word		9	1.00	0	775	97.0	605	100.0
wagon	Control Word		5	1.74	0	600	97.0	602	100.0
walnut	Control Word		6	1.04	0	637	97.0	583	100.0
wash	Control Word		4	1.57	11	663	94.0	546	100.0
waterfall	Control Word		9	0.30	0	639	100.0	578	100.0
wave	Control Word		4	1.66	14	617	97.0	548	100.0
wave	Control Word		4	1.66	18	617	97.0	548	100.0
wire	Control Word		4	1.62	16	601	100.0	573	100.0

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
wolf	Control Word		4	0.78	2	582	94.0	565	100.0
baif	Control Non-Word		4		3				
baps	Control Non-Word		4		13				
bazed	Control Non-Word		5		7				
bedj	Control Non-Word		4		1				
berv	Control Non-Word		4		1				
binc	Control Non-Word		4		3				
birf	Control Non-Word		4		2				
blait	Control Non-Word		5		2				
blawnt	Control Non-Word		6		0				
boam	Control Non-Word		4		7				
boarm	Control Non-Word		5		2				
boart	Control Non-Word		5		3				
bost	Control Non-Word		4		13				
brean	Control Non-Word		5		3				

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
chail	Control Non-Word		5		2				
chawd	Control Non-Word		5		1				
chilm	Control Non-Word		5		2				
chote	Control Non-Word		5		4				
cloom	Control Non-Word		5		2				
coaft	Control Non-Word		5		2				
davt	Control Non-Word		4		2				
dilotaf	Control Non-Word		7		0				
dryn	Control Non-Word		4		0				
ehp	Control Non-Word		3		0				
famp	Control Non-Word		4		6				
fet	Control Non-Word		3		20				
flerch	Control Non-Word		6		0				
flers	Control Non-Word		5		2				
floke	Control Non-Word		5		3				

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
flove	Control Non-Word		5		2				
foaj	Control Non-Word		4		2				
foarn	Control Non-Word		5		0				
frete	Control Non-Word		5		1				
fulm	Control Non-Word		4		2				
fusc	Control Non-Word		4		2				
fyce	Control Non-Word		4		1				
gair	Control Non-Word		4		6				
gawlt	Control Non-Word		5		0				
gerhn	Control Non-Word		5		0				
gfe	Control Non-Word		3		1				
ghyt	Control Non-Word		4		0				
haiv	Control Non-Word		4		2				
hant	Control Non-Word		4		12				
helked	Control Non-Word		6		1				

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
hixa	Control Non-Word		4		0				
hoaj	Control Non-Word		4		1				
hoalt	Control Non-Word		5		0				
kinterat	Control Non-Word		8		0				
klain	Control Non-Word		5		2				
koez	Control Non-Word		4		0				
koog	Control Non-Word		4		0				
kruhmp	Control Non-Word		6		0				
lagido	Control Non-Word		6		0				
larvol	Control Non-Word		6		1				
leext	Control Non-Word		5		0				
loart	Control Non-Word		5		0				
loun	Control Non-Word		4		6				
majanys	Control Non-Word		7		0				
makt	Control Non-Word		4		4				

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
mamths	Control Non-Word		6		0				
mawg	Control Non-Word		4		0				
mydz	Control Non-Word		4		0				
nalp	Control Non-Word		4		0				
nasc	Control Non-Word		4		0				
nohr	Control Non-Word		4		0				
nol	Control Non-Word		3		9				
nynd	Control Non-Word		4		0				
nyre	Control Non-Word		4		3				
perlem	Control Non-Word		6		0				
phek	Control Non-Word		4		2				
phlast	Control Non-Word		6		0				
phlur	Control Non-Word		5		0				
phryve	Control Non-Word		6		0				
plawg	Control Non-Word		5		0				

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
plinc	Control Non-Word		5		0				
prich	Control Non-Word		5		2				
prud	Control Non-Word		4		1				
pryf	Control Non-Word		4		1				
ralp	Control Non-Word		4		2				
ricop	Control Non-Word		5		0				
rytorac	Control Non-Word		7		0				
sair	Control Non-Word		4		7				
saurnosi	Control Non-Word		8		0				
sehn	Control Non-Word		4		2				
shait	Control Non-Word		5		2				
sheem	Control Non-Word		5		4				
shoap	Control Non-Word		5		1				
shoath	Control Non-Word		6		1				
shyce	Control Non-Word		5		0				

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
shype	Control Non-Word		5		1				
sirk	Control Non-Word		4		6				
skaje	Control Non-Word		5		1				
skoze	Control Non-Word		5		0				
smiew	Control Non-Word		5		0				
snue	Control Non-Word		4		2				
sofe	Control Non-Word		4		6				
spawl	Control Non-Word		5		2				
stete	Control Non-Word		5		1				
stralk	Control Non-Word		6		0				
stroat	Control Non-Word		6		0				
sulrin	Control Non-Word		6		0				
swhin	Control Non-Word		5		1				
swoam	Control Non-Word		5		0				
talpiros	Control Non-Word		8		0				

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
tase	Control Non-Word		4		9				
teap	Control Non-Word		4		10				
teeld	Control Non-Word		5		0				
terket	Control Non-Word		6		0				
theen	Control Non-Word		5		1				
thraif	Control Non-Word		6		0				
todamo	Control Non-Word		6		0				
toov	Control Non-Word		4		3				
trean	Control Non-Word		5		2				
tufe	Control Non-Word		4		3				
veeb	Control Non-Word		4		2				
vyfe	Control Non-Word		4		0				
wawf	Control Non-Word		4		1				

Item	Stimulus Type	Pseudohomophone	No. Letters [a]	Log Word Frequency [a]	No. Orthographic Neighbors [a]	Lexical Decision RT (ms) [b]	Lexical Decision % Accuracy [b]	Word Naming RT (ms) [b]	Word Naming % Accuracy [b]
weme	Control Non-Word		4		1				
woaf	Control Non-Word		4		3				
zoash	Control Non-Word		5		0				

Note. RT = reaction time.

[a] Data were compiled using the N-Watch program (Davis, 2005). [b] Normed data available through the English Lexicon Project (Balota et al., 2007).

VITA

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Education

2008 (expected)	Ph.D. in Cognitive Psychology, The Pennsylvania State University
2005	M.S. in Cognitive Psychology, The Pennsylvania State University
2003	B.A. in Psychology, Butler University

Selected Honors and Awards

PSU College of Liberal Arts Dissertation Support Grant (Spring 2008)
PSU Graduate Teaching Fellowships (Fall 2005 – Spring 2007)
National Science Foundation Graduate Research Fellowship Honorable Mention (Spring 2004)
PSU University Fellowship (Fall 2003)

Selected Publications

Linck, J.A., Hoshino, N., & Kroll, J.F. (under review). Cross-language lexical processes and inhibitory control. Paper invited for *The interface between L2 vocabulary learning and representation*, a special issue of *Mental Lexicon*.

Linck, J.A., Kroll, J.F., and Sunderman, G. (in preparation). Learning a second language during immersion: Evidence for increased inhibitory control.

Kroll, J.F., & Linck, J.A. (2007). Representation and skill in second language learners and proficient bilinguals. In I. Kecskes & L. Albertazzi (Eds.), *Cognitive aspects of bilingualism* (pp. 237-269). New York: Springer.

Selected Presentations

Linck, J.A., Bobb, S.C., Hoshino, N., Cheng, K., & Kroll, J.F. (2006). *Bilingualism and inhibitory control: A cross-linguistic comparison.* Poster presented at the 47th annual meeting of the Psychonomic Society, November 17-19, Houston.

Linck, J. A., & Kroll, J. F. (2005). *Increased inhibitory control during second language immersion.* Poster presented at the 46th annual meeting of the Psychonomic Society, November 10-12, Toronto.

Linck, J. A., & Kroll, J. F. (2005). *Language processing during study abroad: Evidence for increased inhibitory control.* Paper presented at the 5th International Symposium on Bilingualism, March 20-23, Barcelona, Spain.

Linck, J. A. (2003). *Negative evidence in Spanish: The effects of adult corrections on the grammaticality of children's speech.* Paper presented at the 15th annual Butler University Undergraduate Research Conference, April 11, Indianapolis.

Linck, J. A., & Bohannon III., J. N. (2003). *Negative evidence in Spanish*. Poster presented at the biennial meeting of the Society for Research in Child Development, April 24-27, Tampa, FL.