Syntactic Processing and Cross-Linguistic Structural Priming in Heritage Spanish Speakers and Late Bilinguals: Effects of Exposure to L2 English on Processing Illicit Structures in L1 Spanish

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EFFECTS OF EXPOSURE TO L2 ENGLISH ON PROCESSING ILLICIT STRUCTURES IN L1 SPANISH

by

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ABSTRACT

Syntactic Processing and Cross-Linguistic Structural Priming in Heritage Spanish Speakers and Late Bilinguals: Effects of Exposure to L2 English on Processing Illicit Structures in L1 Spanish

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This study examines real-time heritage language syntactic processing and tests the hypothesis that some commonly observed properties of heritage languages—apparent instability in grammatical knowledge and divergence from monolingual grammatical norms—can be attributed to cross-linguistic influence from the socially dominant language during online processing. To test this hypothesis, a novel cross-linguistic structural priming experiment based on self-paced listening was conducted with a group of heritage Spanish speakers and late Spanish-English bilinguals to test whether exposure to preposition stranding in English—a feature of core syntax that does not exist in Spanish—could facilitate processing of (ungrammatical) preposition stranding in a subsequently encountered Spanish sentence. Results were subjected to group-level and individual differences analyses with mixed-effects modeling to determine whether any measurable priming effects were influenced by individual differences in exposure, use, and proficiency for Spanish and English.

The results indicate that exposure to preposition stranding in English primed the comprehension of structurally-parallel, but illicit, Spanish sentences for some heritage speakers and all late bilinguals. Heritage speakers who had lower fluency in Spanish than English did not show a priming effect, but they processed Spanish preposition-stranded sentences the fastest and gave higher acceptability ratings, suggesting that preposition stranding may be a feature of their Spanish. An analysis of within-language cumulative priming also revealed that repeated exposure to Spanish preposition-stranded sentences facilitated processing for some late bilinguals. No cumulative priming effect was found among heritage speakers and, for both groups, repeated exposure to Spanish preposition-stranded sentences did not modulate the cross-linguistic priming effect. These findings suggest that while some late bilinguals
implicitly learned to process Spanish preposition stranding over the course of the experiment (Loebell & Bock, 2003), the cross-linguistic priming effect is most compatible with the structural priming account based on residual activation of abstract syntactic representations shared between Spanish and English (Hartsuiker, Pickering, & Veltkamp, 2004).

An analysis of baseline syntactic processing for a separate set of complex grammatical Spanish sentences also showed that heritage speakers and late bilinguals processed these sentences similarly. Like the processing results for Spanish preposition-stranded sentences, heritage speakers showed a processing advantage over late bilinguals. Heritage speakers who were more fluent in Spanish than English also patterned like late bilinguals (showing slower response times) and some late bilinguals but no heritage speakers showed evidence of cumulative priming. Acceptability judgment results also aligned with baseline syntactic processing and cross-linguistic priming results in that heritage speakers who had higher fluency in Spanish than English patterned like late bilinguals. While these results suggest that Spanish preposition stranding may not be entirely ungrammatical for heritage speakers who have significantly higher fluency in English than Spanish, heritage speakers who had higher fluency in Spanish than English were qualitatively identical to late bilinguals in terms of syntactic processing for grammatical and ungrammatical complex sentences, cross-linguistic priming, and grammatical representations.

Taken together, the results of the present study suggest that relative fluency in the heritage and dominant language is the most important predictor of heritage language syntactic processing and grammatical representations. These results also provide some of the first evidence that core syntactic processing in the first-learned language is susceptible to influence from a later-learned language for simultaneous, early sequential, and late bilinguals. Together, the findings of this study lend empirical support to the central concept of Putnam and Sánchez’s (2013) model of heritage language grammar and provide indirect evidence that some heritage language characteristics that are regularly observed in heritage language studies using offline measures may be due in part to real-time influence from the dominant language during heritage language processing.
For Sarah
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**List of Abbreviations**

BLP – Bilingual Language Profile
CNP – complex noun phrase
DO – double object
DOM – differential object marking
ERP – event-related potential
FF – formal feature
HS – heritage speaker
L1 – first-learned language
L2 – second-learned (or later-learned) language
LB – late bilingual
NP – noun phrase
OVS – object-verb-subject
PF – phonological feature
PO – prepositional object
PP – pied-piped
PS – preposition-stranded
RC – relative clause
RT – response time
SR – Serial Response
TAM – tense-aspect-mood
TEPR – task-evoked pupillary response
VP – verb phrase
CHAPTER 1: INTRODUCTION

THE GOAL OF THE PRESENT STUDY

The rapid growth of experimental research focused on heritage language bilingualism during the past two decades has generated new questions regarding the stability of grammatical knowledge acquired naturalistically from birth. HERITAGE SPEAKERS are bilinguals who were raised speaking a social minority language at home from birth and experienced a shift in dominance to the social majority language following exposure to this language during childhood. By and large, as a result of this shift in dominance to the social majority language, the heritage language changes to such an extent that its end state has often been characterized in terms of ‘incomplete acquisition’. While these findings have clearly demonstrated heritage language differences, much current debate in the heritage language literature has focused on determining the appropriate characterization of the processes that are responsible for these differences. Research in this area has largely taken the approach of mapping grammatical domains that are susceptible to change across various heritage languages and then relating these changes to aspects of the developmental context of heritage speaker bilingualism (Montrul, 2016; Pascual y Cabo, 2015). This research has focused almost exclusively on exploring changes in heritage language GRAMMATICAL REPRESENTATIONS, and as a result, these studies have relied primarily on offline experimental methods such as acceptability judgments to probe abstract grammatical knowledge. In contrast, very few studies have focused on exploring how heritage language grammatical knowledge is accessed and implemented during ONLINE LANGUAGE PROCESSING (Bolger & Zapata, 2011).

During this same period, research on bilingual language processing has also seen marked growth. Empirical findings in this research area have shown that during bilingual language production and comprehension, grammatical representations from both languages are activated at all levels, from phonology to syntax. Even when experiments have required use of only one language, this research has shown that bilinguals cannot completely inhibit grammatical representations in their other language (Hatzidaki, Branigan, & Pickering, 2011). At the level of syntactic processing, an experimental paradigm known as CROSS-LINGUISTIC STRUCTURAL PRIMING has allowed researchers to pinpoint how activation of grammatical knowledge in one of a bilingual’s languages can influence online syntactic processing in the
other language. A central question that has emerged in this research is whether cross-linguistic influence on syntactic processing reflects activation of abstract grammatical representations that are shared between a bilingual’s languages (Hartsuiker et al., 2004) or rather implicit learning of processing procedures for the syntactic structures in question (Loebell & Bock, 2003). Different studies have shown evidence for both accounts, however research in this area has focused almost exclusively on syntactic processing for structures that are grammatical in both of a bilingual’s languages. Crucially, there have been few studies that have examined whether activation of grammatical representations or processing procedures for a syntactic structure that a priori exists in only one of a bilingual’s languages also influences subsequent syntactic processing in the other language.

The goal of the present study is to address the significant gap in our understanding of heritage language online processing by determining whether activation of grammatical knowledge that is a priori specific to heritage speakers’ dominant language can influence syntactic processing in their heritage language. To address this goal, a cross-linguistic structural priming paradigm was used to test influence of exposure to English on real-time syntactic processing in Spanish for two groups of bilinguals: heritage Spanish speakers and late Spanish-English bilinguals. In addition to describing the similarities and differences between heritage language syntactic processing and late bilingual first language (L1) syntactic processing, the experiment was designed to test the idea that cross-linguistic influence during heritage language online processing may be responsible for some of the unique features of heritage languages that have been attributed to differences in representational knowledge in studies that have used offline methods. While heritage language research has focused mainly on high-level processes of change like arrested development, attrition, and cross-linguistic influence on representation, few studies have focused on elucidating the mechanisms that underlie these processes. The present study addresses this gap by testing the central concept of one mechanism that has been proposed to account for the trajectory and ultimate outcome of heritage language acquisition based on fluctuating activation levels between heritage language lexical items and dominant language grammatical features (Putnam & Sánchez, 2013).

By bringing insights and methods from psycholinguistic research on bilingual language processing to address questions about how heritage speakers access and implement grammatical
knowledge in real time, the present study aims to uncover the mechanisms that play a role in shaping heritage language acquisition and change throughout the lifespan. This study raises new and interesting questions about the stability and permeability of L1 syntactic processing following acquisition of a second language (L2) and, given that heritage speakers are one type of bilingual, the results have broader implications for our understanding of bilingualism generally and the human language faculty (Benmamoun, Montrul, & Polinsky, 2013b; Rothman & Treffers-Daller, 2014).

HERITAGE LANGUAGE DIFFERENCES

A central finding in heritage language experimental research is that heritage speakers show evidence of DIVERGENCE and INSTABILITY in grammatical knowledge that varies within and across heritage language domains. While knowledge of heritage language core syntax has largely been reported to show little evidence of instability or divergence, heritage language morphosyntax has been found to be particularly unstable (Montrul, 2016). Whereas monolinguals or late bilinguals who speak the heritage language as their L1 are regularly reported to perform similarly on offline measures of grammatical knowledge across related morphosyntactic phenomena, heritage speakers have often been reported to perform less consistently on these tasks, showing considerable variation between related areas of grammar (Montrul, 2006) and from one individual to the next (Benmamoun, Montrul, & Polinsky, 2010; Montrul, 2016). To account for this instability and divergence, various proposals have suggested that heritage speakers experience a combination of arrested development of the heritage language, attrition of previously-acquired heritage language knowledge, or cross-linguistic influence from the dominant language which results in changes in heritage speakers’ grammatical representations. While these accounts may adequately describe the characteristics of a heritage language grammar at a specific point in time, there have been few models offered to explain the mechanisms at work in each of these processes.¹

One notable exception is the generative model put forth in Putnam and Sánchez (2013) which ascribes instability and divergence across heritage language grammatical areas to changes in the

¹ See Bayram (2013) for a summary of critiques related to the lack of theoretical models in heritage language acquisition research.
strength of activation between heritage language lexical items and competing functional feature or constraint values associated with the heritage and dominant languages. According to this model, increased processing of dominant language input strengthens the activation level between heritage language lexical items and the grammatical features that are instantiated in the dominant language. While this model predicts that activation of dominant language grammatical features or constraint values will increase in the heritage language following processing of dominant language input, this prediction is not easily tested in the domain of morphosyntax given that differences in formal feature values often correspond to the absence or presence of inflectional morphemes that express these features. For instance, in the case of heritage Spanish speakers’ reduced sensitivity to verbal inflections expressing mood in Spanish (Montrul, 2007, 2009; Silva-Corvalán, 1994b), it is difficult to determine whether this linguistic behavior indicates increased activation of the grammatical features of the dominant language, English, which does not express mood with inflectional morphology, or simply absence of mood as a morphosyntactic feature in these individuals’ Spanish.

Given this practical concern and the evidence that some aspects of heritage language core syntax have also been found to show signs of instability (Cuza, 2013; Pascual y Cabo & Soler, 2015), the present study focuses on testing the influence of dominant language activation on heritage language processing in the domain of core syntax. Unlike in the domain of morphosyntax, where instability and divergence cannot be unambiguously linked to dominant language influence during heritage language processing, the mechanism proposed in Putnam and Sánchez (2013) can be straightforwardly tested in the domain of syntax using a cross-linguistic structural priming paradigm since differences between grammatical feature or constraint values in the heritage and dominant language correspond to differences in syntactic configurations (rather than presence vs. absence of a linguistic unit). Furthermore, structural priming is a well-established method in psycholinguistics and recent findings from cross-linguistic structural priming studies are available to guide interpretation of the results in the present study (Kootstra & Muysken, 2017; Pickering & Ferreira, 2008).

**BILINGUAL SYNTACTIC INTEGRATION AND CROSS-LINGUISTIC INFLUENCE**

Although research on bilingual syntactic processing is relatively new, it has already produced important findings that have shed light on the ways in which both short and long term changes in
language exposure and use can impact how bilinguals access and implement syntactic knowledge to process language in real time (Dussias, 2004; Dussias & Sagarra, 2007). The evidence that use of one language has an immediate effect on syntactic processing in the other language has come from studies based on the cross-linguistic structural priming paradigm. This technique is based on the within-language structural priming paradigm (Bock, 1986; Pickering & Ferreira, 2008), which has shown across languages that during language production an individual is more likely to repeat a linguistic structure that they have recently been exposed to or have recently produced themselves, and during language comprehension, recently encountered structures are easier to process. Since Loebell and Bock’s (2003) study investigating cross-linguistic structural priming among German-English bilinguals, cross-linguistic priming studies have consistently shown that hearing or using a syntactic structure in one language promotes its use in the other language, although this influence is modulated by proficiency in each language among other factors (Bernolet, Hartsuiker, & Pickering, 2013).

To date, cross-linguistic structural priming studies have focused on structures that exist in both of a bilingual’s languages (such as the passive construction in Spanish and English) and have concluded that processing these structures in either language draws on a shared set of syntactic representations (Hartsuiker et al., 2004) or structure building procedures (Loebell & Bock, 2003). While a few recent studies have also shown that cross-linguistic priming occurs for syntactic structures that are licit but dispreferred in the target language (Carando, 2015; Hsin, Legendre, & Omaki, 2013), a possibility that has not been explored is whether cross-linguistic priming can also make abstract structures and/or structure building procedures that are a priori specific to only one of a bilingual’s languages available during syntactic processing in the other language. To test this possibility, the present study focused on cross-linguistic structural priming for a core syntactic constraint that differs between Spanish and English: PREPOSITION STRANDING. Preposition stranding refers to a syntactic operation in which a prepositional object has been moved, for example during formation of a wh-question or relative clause, while the preposition that selects for the prepositional object remains in its base position. While a commonly occurring feature of English wh-questions and relative clause sentences, preposition stranding does not occur in Spanish (Law, 2006; Zagona, 2002).
OVERVIEW

Putnam and Sánchez’s (2013) model holds that heritage language grammatical development and change is driven by fluctuations in the level of activation between heritage language lexical items and their associated grammatical feature or constraint values. Processing input in the heritage and dominant language that instantiates a grammatical feature or constraint strengthens its activation and, as a result, this model predicts that processing dominant language input will activate dominant language grammatical feature or constraint values that will affect subsequent heritage language syntactic processing. The present study tests this prediction using a cross-linguistic structural priming paradigm to measure the extent to which activation of preposition stranding in English affects syntactic processing for preposition stranding in heritage Spanish.

We are just beginning to understand the unique properties of bilingual language processing. Structural priming reflects momentary changes in syntactic processing and that cross-linguistic priming effects provide evidence that a bilingual’s languages share a single set of abstract syntactic representations or structure building procedures, at least for syntactic structures that are instantiated independently in each of the two languages. What remains to be discovered is the extent to which syntactic features that exist in only one of a bilingual’s languages exert an influence during syntactic processing in the other language. The present study contributes to the growing experimental research on both heritage language bilingualism and bilingual syntactic processing by exploring the extent of cross-linguistic influence during L1 syntactic processing for two groups of bilinguals that are similar in their order of language acquisition but differ in their relative proficiency, patterns of use, and amount of exposure for each language.

The remainder of the present study is organized as follows: Chapter 2 situates this work in the field in heritage language research, summarizing the major empirical findings in this area, as well as the accounts that have been given to explain the unique characteristics of heritage languages. Chapter 3 further contextualizes the present study in the larger field of bilingualism research that has focused on cross-linguistic interaction and integration during online bilingual language processing. This chapter begins with a summary of the empirical evidence related to language integration and bilinguals’ inability to selectively access and inhibit their languages during language production and comprehension before
turning to research that has shown evidence of cross-linguistic influence at the level of syntactic processing, and concluding with a more in depth examination of the primary method employed in this research and in the present study: cross-linguistic structural priming. Chapter 4 introduces an empirical study to test dominant language influence during heritage language syntactic processing and outlines the research questions and experimental design. Chapter 5 presents the analysis and results of the empirical study, including by-group comparisons of baseline syntactic processing, cross-linguistic structural priming, and acceptability judgments for heritage speakers and late bilinguals, as well as within-group analyses of the influence of several factors related to the context of heritage language development and use. Chapter 6 provides an interpretation of the findings and discusses the implications for theories of heritage speaker bilingualism and language integration and interaction more broadly before concluding with some recommendations for further study.
CHAPTER 2: HERITAGE LANGUAGES AND THEIR PROPERTIES

INTRODUCTION

In cases of simultaneous or early sequential bilingualism, there is often a difference in the social status between a bilingual’s two languages. In the case where a language acquired naturalistically from birth in the home is not regularly used in the wider society, this language is referred to as a HERITAGE LANGUAGE (Montrul, 2016; Rothman, 2009; Valdés, 2001). While use of the term heritage language is mostly confined to Canada and the United States, heritage languages are found around the world, wherever there is immigration and the language(s) spoken by immigrant populations are not widely encountered outside of the home or immediate speaker community (Benmamoun et al., 2013b). Speakers of heritage languages gained widespread attention in the United States starting in the 1970s from educators who were concerned primarily with developing effective pedagogical practices for teaching heritage languages in high school and college language courses that had been designed with principles of foreign language learning in mind and proved to be ineffective for these bilinguals (Valdés, 1997). While the term HERITAGE LANGUAGE SPEAKER or HERITAGE SPEAKER has been used in certain contexts to refer to any individual who has a personal connection to a social minority language, whether or not they possess any ability to speak or understand the language (Carreira, 2004), among educators and linguists this label is typically reserved for bilinguals who acquired a heritage language naturalistically from birth and maintain some command of the heritage language beyond childhood (Benmamoun, Montrul, & Polinsky, 2013a; Polinsky & Kagan, 2007; Valdés, 2001). The focus of the present study is on the latter category of heritage speakers—bilinguals who maintain proficiency in a heritage language into adulthood.

Beginning in the mid-1990s, heritage speaker bilingualism became a topic of interest among experimental linguists who were interested in understanding how the unique circumstances of heritage

2 Outside of the U.S. and Canada, terms such as MINORITY LANGUAGE SPEAKER or HOME BACKGROUND SPEAKER are more frequently used to refer to bilinguals who acquire and use social minority languages in these circumstances.

3 The term heritage language is also used to refer to the languages spoken by indigenous communities in the U.S. (Wiley, 2001) though, for the present study, the focus is on heritage languages in the context of immigration.
language acquisition related to ultimate attainment in the heritage language (Montrul, 2016). Since then, a vast number of studies that have focused on various linguistic features across a typologically diverse set of heritage languages have firmly established that exposure to a socially-dominant language early in life, either concurrently with the heritage language for simultaneous bilinguals or during childhood for early sequential bilinguals, has long-term effects on the properties and use of the heritage language.

From this body of work, several general trends have emerged—chief among them, the ubiquitous finding that heritage speakers typically report feeling more proficient, dominant, or ‘stronger’ in the social majority language compared to the heritage language (Scontras, Fuchs, & Polinsky, 2015). The contrast between language dominance and the order of acquisition (at least for early sequential bilinguals) is often discussed as one of the hallmark traits of heritage speaker bilingualism (Rothman, 2009). The shift in dominance from the home language to the majority language is often attributed to the fact that the introduction of the majority language early in life reduces the overall quantity of input received in the heritage language (Montrul, 2009; Rothman, 2009) and increased used of the majority language changes the quality of the heritage language input (Stafford & Azevedo, 2015). Heritage language input continues to be received from members of the family and perhaps the local speaker community and likewise use of the heritage language by the learner becomes relegated to a more limited set of domains and functions mostly associated with family and home life, while the dominant language becomes that language of choice for socializing outside of the home or speaker community (Grosjean, 2016; Polinsky, 2016).

Like monolinguals, heritage speakers acquire the language of their caregivers naturalistically from birth but, unlike monolinguals, the outcomes of heritage language acquisition vary widely—from full productive ability in the heritage language at one end of the spectrum to limited receptive skills at the other (Montrul, 2016). It is common for heritage speakers to be introduced to the majority language during early childhood upon entering school, where the heritage language is often times not used at all (Beaudrie & Fairclough, 2012). As a result of completing all or most of their formal education in the majority language, heritage speakers often lack literacy skills in their heritage language commensurate with their reading and writing abilities in their dominant language (Beaudrie & Fairclough, 2012; Menken & Kleyn, 2010; Tse, 2001). Relatedly, heritage speakers are also typically characterized as lacking metalinguistic awareness of the heritage language (Bowles, 2011) while these same skills are more
developed for the dominant language through formal education. Adult monolinguals control use of their language across registers, contexts, and for a range of functions. In contrast, adult heritage speakers vary widely in their literacy skills, command of registers, and ability to use the home language effectively for various functions (Chevalier, 2004; Polinsky, 2016).

These basic differences between the outcomes of heritage language acquisition and monolingual first language acquisition have prompted researchers to ask whether and to what extent heritage speakers differ from monolinguals in their underlying linguistic competence. The idea that heritage speakers differ from monolinguals in not just their ability to use the language they acquired naturally from birth but also in the tacit grammatical knowledge they possess of the language has fueled much of the research from a formal linguistic perspective that has sought to describe not only how heritage speaker competence differs from monolingual competence but also to determine what processes are responsible for the differences (Rothman, Tsimpi, & Pascual y Cabo, 2016).

**EMPIRICAL FOUNDATIONS**

There is a long tradition in the sociolinguistic literature focusing on intergenerational language change in language contact situations (Nagy, 2015; Otheguy & Zentella, 2012; Silva-Corvalán, 1994a; Torres, 1989). This line of inquiry has focused on describing how the languages spoken in immigrant communities change over time from one generation to the next: from first-generation immigrants (those who immigrated as adults, commonly referred to as first immigrant generation bilinguals or first-generation bilinguals), to their children, who were born in the new country or were brought before adolescence (second immigrant generation bilinguals or second-generation bilinguals), and sometimes through transmission of the home language to their children, the third generation. The general findings from this body of work, which is based primarily on data collected via spontaneous production in a natural setting, show sometimes drastic shifts in the home language forms produced from one generation to the next. One common result of these large intergenerational shifts is that the heritage language often ceases to be used after the third generation, at least in the U.S. (Rumbaut, 2009). While this body of work has provided valuable insight into the domains of language that tend to change over time in language contact environments and how these changes are shaped by social factors and contact with speakers of other languages, the present study and the remainder of this chapter focus on a more
recent area of research that has sought to elucidate aspects of heritage speaker linguistic competence through experimental methods.

Like the sociolinguistic approaches to studying heritage speakers, the experimental approaches have largely focused on differences in linguistic knowledge between heritage speakers and other populations who speak the heritage language. Unlike the sociolinguistic literature, which has focused on differences between generations of speakers from within the same speaker community (e.g., Silva-Corvalán, 1994a), the vast majority of experimental studies have compared heritage speakers to baseline comparison groups from outside the speaker community, such as monolinguals residing in other countries (e.g., Montrul, 2006, 2010a; Polinsky, 2011), late bilinguals who acquired the heritage language from birth and learned the social majority language in adulthood but are not members of the immigrant speaker community (such as students on temporary stays abroad) (e.g., Cuza, 2013; Montrul, 2002; Montrul, de la Fuente, Davidson, & Foote, 2013), and adult second language learners who acquired the social majority language from birth and learned the heritage language as adults in a school setting (e.g., Montrul, 2010a, 2010b; Montrul & Ionin, 2010; Rothman, 2007).

Setting aside the potential methodological issues with the comparison groups that have been used in this approach (see Pascual y Cabo and Rothman (2012) for a discussion on this issue), the use of experimental techniques provides a means to test the tacit grammatical knowledge underlying heritage speakers’ language behavior. The past few decades of experimental work in this area has been extremely fruitful, contributing to the documentation of unique heritage language features and generating a number of new lines of inquiry and findings that are important not just for understanding heritage speaker bilingualism but also for understanding the human language faculty broadly (Benmamoun et al., 2010; Montrul, 2016; Scontras et al., 2015).

**Variation and Instability Within and Across Heritage Language Domains**

The vast majority of heritage language experimental studies have characterized their findings in terms of divergence and instability in grammatical knowledge that varies within and across heritage

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4 For experimental studies that have compared adult heritage speakers to other groups from within the same immigrant community, see Hulsen (2000), Kim, Montrul, and Yoon (2009), and Polinsky (2011).
language domains—including phonology, morphology, syntax, semantics, and pragmatics—compared to native speakers of baseline varieties.\(^5\) Whereas monolinguals or late bilinguals who speak the heritage language as their L1 are regularly reported to give stable linguistic judgments across related linguistic phenomena that align with theoretical predictions, heritage speakers have often been reported to give less determinate judgments that differ from baseline (more in degree than in quality) and vary considerably between related areas of grammar (Montrul, 2006, 2009) and from one individual to the next (Benmamoun et al., 2010; Montrul, 2016).

Heritage speakers and monolinguals differ little in the domain of phonology while comparatively larger and more widespread differences have been documented in the domain of heritage speaker morphology (Montrul, 2013). Except for heritage speakers with limited proficiency in the heritage language, who have been found to exhibit a noticeable ‘non-native’ accent in the heritage language (Benmamoun et al., 2010), moderate and high proficiency heritage speakers typically perform similarly to monolinguals in terms of their ability to produce and perceive phonological contrasts in the heritage language (e.g., Chang, 2016 and references therein). Heritage speakers differ from monolinguals in some aspects of prosody (Rao, 2016), however, these differences may depend on modality, with heritage speakers performing more like monolinguals in perception tasks than in production tasks (Yang, 2015).

In contrast to the limited differences that have been found in heritage speaker phonology, the majority of the claims that have been made about heritage language instability and divergence have been based on studies of heritage language morphology (Montrul, 2016). Within the domain of morphology, the biggest differences in heritage languages have been found in inflectional morphology (Montrul, 2008a). Research in this area has consistently reported findings of simplified tense-aspect-mood (TAM) systems (Montrul, 2002, 2009; Montrul & Perpiñán, 2011; Polinsky, 2006)\(^6\), case (Montrul, 2010a; Montrul & Bowles, 2009; Polinsky, 2006), and gender systems (Montrul, Foote, & Perpiñán, 2008a; Polinsky, 2006).

\(^5\) For studies that have reported no significant differences between heritage speakers and speakers of baseline language varieties, see Leal Méndez, Rothman, and Slabakova (2015) and Montrul (2006, 2010a).

\(^6\) Although heritage Brazilian speakers have been argued to lack knowledge of inflected infinitives, this has been attributed to a lack of access to inflected infinitives in the input since these linguistic forms are only present in European Portuguese dialects, which are only encountered in formal education settings, not in the colloquial Brazilian Portuguese that these heritage speakers are exposed to (Pires & Rothman, 2009; Rothman, 2007).
Within morphosyntax, related grammatical phenomena have been found to exhibit signs of instability and divergence to differing degrees. For example, within the Spanish TAM system, heritage Spanish speakers have been found to perform more like monolinguals in the use of the subjunctive in contexts where it is syntactically required compared to when the subjunctive is optional and its use is conditioned by semantic and pragmatic properties of the utterance. Findings like this have been characterized as evidence of ‘partial knowledge’ of grammatical rules in the heritage language (Rothman, Tsimpli, & Pascual y Cabo, 2016; Silva-Corvalán, 1994a).

In the domain of syntax, heritage speakers typically exhibit monolingual-like knowledge of core syntactic properties, such as knowledge of the syntactic reflexes of unaccusativity and unergativity (Montrul, 2006; Zapata, Sánchez, & Toribio, 2005) and clitics (Montrul, 2004, 2010a) in heritage Spanish (but cf. Cuza (2013) and Pascual y Cabo and Soler (2015), discussed below) but diverge from baseline in aspects of syntax that are governed by semantic, pragmatic, and/or discourse considerations (Bolger & Zapata, 2011; Bullock & Toribio, 2004; Montrul, 2006, 2010a; Rothman et al., 2016; Sorace, 2004).

Research on the use of syntactic structures governed by semantic and discourse-pragmatic knowledge has been conducted within the framework of the INTERFACE HYPOTHESIS (Montrul & Polinsky, 2011; Sorace, 2011, 2012; Sorace & Filiaci, 2006). Among heritage speakers, variability involving interface phenomena has been shown in the use of pragmatically-infelicitous overt arguments (e.g., Keating, VanPatten, & Jegerski, 2011; Polinsky, 2016; and references therein), double-que questions in Spanish (Cuza & Frank, 2011), clitic left dislocations and differential object marking (DOM) in Spanish (Montrul, 2010a), and the interpretation of definite articles in heritage Spanish (Montrul & Ionin, 2010). However, not all studies of interface phenomena among heritage speakers align. In contrast, heritage Spanish speakers have been reported to perform like Spanish monolinguals and late Spanish-English bilinguals residing in the U.S. for more than seven years on tests of interface phenomena involving fronted focus and clitic left dislocation in Spanish (Leal Méndez, Rothman, & Slabakova, 2015).

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7 While studies have found that heritage Spanish speakers may assign gender to specific lexical items differently than monolinguals, they show monolingual-like performance in the syntactic operations involved in nominal gender agreement with determiners and adjectives (Montrul, Foote, & Perpiñán, 2008a).
The main conclusion that has emerged from the differences summarized in this section is that heritage speakers do not reach ‘native-like mastery’ of the heritage language in adulthood (Montrul, 2016; Polinsky, 2016) and these findings have raised questions about the presumed stability of a language acquired naturally from birth (Benmamoun et al., 2010). In general terms, these unique properties of heritage languages have been attributed to exposure to the social majority language in childhood, which, as the primary language of education and socialization outside of the home and local speaker community, led to a reduction in the amount of heritage language input and opportunities for its use during heritage language acquisition. While the introduction of the majority language early in life is responsible for divergent outcomes in heritage language acquisition, there is a lack of consensus on which aspects of introduction of the dominant language are most important in determining the outcome of heritage language acquisition.

**The Role of Language Experience**

A few studies have focused on how factors related to the context of heritage language development relate to the outcomes of heritage language acquisition. In an oral production study, Montrul (2004) found that proficiency in heritage Spanish at the time of testing correlated with degree of divergence in different grammatical areas including the TAM system and pragmatically-felicitous use of overt arguments. Heritage Spanish speakers with intermediate proficiency, as determined by scores on a cloze test and a vocabulary test adapted from the DELE (Diploma de Español como lengua extranjera), showed English-like patterns of overt subject and object use while heritage speakers with high Spanish proficiency patterned like Spanish monolinguals. Similarly, in an investigation of grammatical aspect and mood in heritage Spanish, Montrul (2009) found that high proficiency heritage speakers performed similarly to Spanish-speaking late learners of English in their production and interpretation of aspect and mood morphology, although there were some differences depending on the type of experimental task. In contrast, the production and interpretation of these forms by the intermediate and low proficiency heritage speakers in this study were significantly different from that of the high proficiency and control group.

In a separate study of Spanish tense and aspect distinctions, (Montrul, 2002) also found that heritage Spanish speakers who were exposed to English between ages 0–7 performed differently than Spanish monolinguals and heritage speakers who were exposed to English between ages 8–12, while
only a few heritage speakers in the 8–12 group performed differently than the monolingual group. Similarly, Montrul (2006) found that high proficiency heritage Spanish speakers patterned like Spanish monolinguals in their sensitivity to unaccusativity and unergativity in Spanish, and hypothesized that this knowledge may have been unaffected by exposure to English because this aspect of syntax is acquired very early in life (before age four) as is not dependent on changes in frequency of input or the development of literacy skills in the heritage language, unlike other aspects of grammar (Montrul, 2002).

Lastly, in an offline study of preposition stranding in Spanish—the core syntactic phenomenon that is the focus of the present study—Pascual y Cabo and Soler (2015) found nearly categorical rejection of preposition stranding in three types of Spanish sentences among late Spanish-English bilinguals who were exposed to English after age 16 and heritage Spanish speakers who were exposed to English after age six, while heritage speakers who were exposed to English from birth were more accepting of these structures and produced them significantly more in a written task. In a review of these and other studies that examined the relationship between age of exposure to the dominant language and heritage language development, Montrul (2008) concluded that heritage speakers who are exposed to the dominant language from birth are likely to experience more extensive ‘loss’ of the heritage language compared to heritage speakers who are exposed to the dominant language later in childhood.

While more research is needed in this area to better understand how differences in exposure, use, and proficiency in the heritage and dominant language uniquely contribute to the trajectory and outcomes of heritage language development, the available evidence suggests that age of exposure to the dominant language during childhood and level of proficiency in the heritage language in adulthood are important predictors of adult heritage speakers’ linguistic performance on offline measures of grammatical knowledge.

**PROPOSED SOURCES OF HERITAGE LANGUAGE DIFFERENCES**

As with many linguistic phenomena, a first question that can be asked of heritage speakers’ linguistic behaviors is whether they are rooted in differences in grammatical representation or processing. To date, most accounts that have been given to explain the hallmark heritage language properties described above cite changes in linguistic representation that result from some combination of arrested development (sometimes referred to as interrupted acquisition as in Albirini and
Benmamoun (2014)), \textsc{attrition}, \textsc{divergent input}^8, and \textsc{cross-linguistic influence} (also referred to as \textsc{transfer} in some work, such as Polinsky (2016)). In comparison, accounts that are rooted in real-time processing influence have been framed almost exclusively in terms of \textsc{processing limitations} under the Interface Hypothesis. With the exception of divergent input, the main features of each of these accounts and their explanatory adequacy will be briefly summarize in the next sections. The summaries will conclude with a review of Putnam and Sánchez’s (2013) model of cross-linguistic influence in heritage language grammar, which provides a conceptual framework for considering an additional type of real-time influence on heritage speakers: \textsc{cross-linguistic influence on processing}.

\textbf{Arrested Development}

The most often cited source of heritage language instability and divergence from baseline in the experimental literature has been arrested development, although the term \textsc{incomplete acquisition} of the heritage language is more often used (Benmamoun et al., 2010; Bolger & Zapata, 2011; Montrul, 2002, 2004, 2008a, 2008b; Polinsky, 2006, 2008). The term incomplete acquisition has been used throughout the heritage language literature to refer to both the outcome of heritage language acquisition (in the sense of a heritage speaker failing to acquire monolingual-like grammatical competence) and a process that contributes to this ultimate outcome (in the sense of arrested development). This term has been controversial due to its common use in the literature to refer the end state of heritage language acquisition and the connotation of ‘language deficit’ (Kupisch & Rothman, 2016; Otheguy, 2016; Otheguy & Zentella, 2012; Pascual y Cabo & Rothman, 2012; Putnam & Sánchez, 2013). The debate about

\footnotesize{\begin{itemize}
\item While incomplete acquisition and attrition have long dominated conversations around the source(s) of heritage language properties, a growing number of critics have suggested alternative explanations for the properties of heritage languages that are rooted in differences in input (Otheguy, 2016; Pascual y Cabo & Rothman, 2012; Pires & Rothman, 2009; Putnam & Sánchez, 2013). One of the main criticisms is that heritage speakers may have never encountered monolingual-like input due to their caregivers (first-generation bilinguals) experiencing attrition prior to providing the heritage language input (Montrul, 2008) and, in other cases, heritage speakers lacking exposure to environments (such as formal education) where a specific feature would appear (Pires & Rothman, 2009; Rothman, 2007). Under this account, differences between heritage speakers and monolinguals amount to dialectal differences (Rothman, Tsimpli, & Pascual y Cabo, 2016). It is important to note that this explanation does not make any suggestion of incomplete acquisition or attrition of the heritage language. In the divergent input account, heritage speakers are never exposed to the target forms in the first place, which explains why they are not acquired. This idea will not be explored further, since the present study is focused heritage speakers who have been exposed to the target structures but show non-target-like behavior.
\end{itemize}}
whether incomplete acquisition is the correct characterization of heritage language ultimate attainment will not be addressed here since this section and the present study as a whole focuses on the processes that shape heritage language acquisition and use, rather than the outcomes per se. Given this focus, and to avoid confusion due to the dual uses of the term incomplete acquisition, the term arrested development is used here instead.

In the case of heritage speakers, explanations based on arrested development hold that introduction of the majority language halts or interrupts the acquisition of a given heritage language property before the individual has arrived at a corresponding linguistic representation that is consistent with the input received. However, these explanations are not always clear as to whether the interruption is indirectly related to the majority language—i.e., increased use of the majority language leading to a reduction in heritage language input, which ultimately causes the interruption (Montrul, 2016)—or whether the relationship is more direct—i.e., exposure to a contrasting feature in the majority language interfering with the acquisition of the corresponding feature in the heritage language.

The exact role played by changes in the quantity and quality of heritage language input in determining the course and outcome of heritage language acquisition is the topic of current debate. In describing incomplete acquisition, Montrul (2016) states “[i]t is very likely that due to insufficient exposure [heritage speakers] did not receive the minimum threshold of input required to acquire and master different aspects of morphology and syntax…” (p. 124). However, as Montrul acknowledges in the following sentence, we have not yet been able to quantify the minimum input necessary to acquire different aspects of linguistic knowledge. This fact, paired with the widely-accepted idea that monolingual children successfully and uniformly acquire a grammar consistent with the input they receive despite wide difference in the amount of input and errors and inconsistencies in the input (Chomsky, 1980) call into question the importance of the reduction of heritage language input per se in determining heritage language properties.

Regardless of the underlying mechanism(s), the main concept of the arrested development account is that heritage speakers fail to acquire a feature of the language that is present in the input they received during the acquisition period. While this account has some intuitive appeal and provides a seemingly adequate description of the outcome of heritage language acquisition, the fact that this account
does not include an explicit formal mechanism that explains the process of arrested development limits its usefulness as an explanatorily-adequate account of heritage language acquisition and use.

**Attrition**

Following incomplete acquisition, attrition has been the second most cited account of heritage language properties (Benmamoun et al., 2010; Polinsky, 2011). The attrition account holds that heritage speakers successfully acquire knowledge of a grammatical feature present in the heritage language input, but this knowledge is then lost at some later point (Montrul, 2006, 2016). Attrition in the heritage language does not always entail complete loss; rather, it has been characterized as **STRUCTURAL REANALYSIS, PARADIGM SIMPLIFICATION, or EXTENSION** of successfully acquired heritage language forms to new linguistic environments (Hopp & Putnam, 2015). For example, Polinsky (2011) argues that relative clause structures in heritage Russian that were successfully acquired in childhood but are difficult to process or infrequently used may be reanalyzed, resulting in a reduced inventory of relative clause structure types in the heritage language. A similar process has been suggested for the restructuring of restrictive relative clauses in heritage Arabic due to processing difficulty (Albirini & Benmamoun, 2014). (See also Polinsky (2016) for similar arguments related to the simplification of heritage language structures that are syntactically or semantically ambiguous.)

As these examples illustrate, some versions of the attrition account go beyond describing heritage language properties and provide a mechanism to explain how loss of grammatical knowledge is related to frequency of use of a structure and its computational complexity. This explanatory mechanism assumes that dominant language acquisition restricts the computational resources available to heritage speakers for processing syntactic relationships relative to monolinguals (e.g., Scontras et al., 2015; Sekerina & Trueswell, 2011). Over time, these processing constraints lead to changes in grammatical knowledge that become stable features of the heritage language.

The next class of accounts of heritage language properties, based on the Interface Hypothesis, are similar to some attrition accounts in that they propose that heritage language processing limitations are responsible for non-target-like use of the heritage language although they differ in the timing of these effects. While the attrition account holds that processing difficulties that were experienced earlier in life led to grammatical reanalysis that subsequently results in divergent yet stable grammatical
representations in the heritage language, processing accounts based on the Interface Hypothesis hold that processing limitations continue to influence heritage language use in real time.

**Processing Differences and the Interface Hypothesis**

The Interface Hypothesis (Sorace & Filiaci, 2006) holds that syntactic properties that are governed by semantic, pragmatic, or discourse information are more likely to show optionality and indeterminacy at the end state of bilingual acquisition or L1 attrition compared to aspects of core syntax, which do not involve integration with other domains (Sorace, 2011). The end-state optionality and indeterminacy associated with these syntactic properties that interface with other domains have been attributed to aspects of processing rather than representation—the extra processing involved in integrating syntactic features with extra-syntactic information in real time has been argued to sometimes overburden the available processing resources, which results in the selection of a default linguistic form, for example, overuse of pragmatically-inappropriate overt subject pronouns in Spanish among Spanish-English bilinguals (Sorace, 2011). While this hypothesis was first proposed to account for “…non-convergence and residual optionality found at very advanced stages of adult second (L2) acquisition…” (Sorace, 2011, p. 1), it has been more recently extended to account for similar language behaviors observed for simultaneous and early bilinguals, including heritage speakers (Montrul & Polinsky, 2011). In the interface account, the bilingual is thought to possess monolingual-like grammatical knowledge relevant to the property in question, but processing limitations interfere with the implementation of this knowledge online. While the exact nature of the bilingual processing limitations that are involved in these phenomena are currently debated, it has been suggested that bilinguals may be less efficient at processing compared to monolinguals because bilingual processing is ‘less automatic’, due to differences in how the relevant grammatical information is stored and/or accessed (Sorace & Serratrice, 2009).

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9 While it is logically possible that non-target-like behaviors involving interface phenomena can be traced to representational differences due to influence from the dominant language rather than processing limitations per se, studies involving bilingual speakers of language pairs with similar interface properties (e.g., use of overt subjects in Spanish and Italian) have shown similar optionality and variability, which supports the processing-based account. See Sorace (2011) and references therein for a detailed discussion on this topic.
In line with previous studies of pronoun use among bilingual children and near-native L2 learners of null subject languages (e.g., Sorace & Filiaci, 2006; Sorace & Serratrice, 2009; Sorace, Serratrice, Filiaci, & Baldo, 2009; Tsimpli, Sorace, Heycock, & Filiaci, 2004), studies on the use of overt subject pronouns among Spanish heritage speakers (Keating, VanPatten, & Jegerski, 2011) and Greek heritage speakers (Kaltsa, Tsimpli, & Rothman, 2015) showed that these groups also extended use of overt subject pronouns to pragmatically infelicitous contexts. These and other studies that have found heritage language differences involving interface phenomena (e.g., Montrul, 2004, 2010; Montrul & Bowles, 2009; Scontras et al., 2015) suggest that reduced processing ability may play a role in shaping various aspects of heritage language use involving interface phenomena.

It is important to note that explanations based on processing limitations have also been given for non-interface phenomena observed for heritage speakers. Beyond the instances of attrition that have been hypothesized to result from processing limitations at an earlier point time, there have been some suggestions that divergent heritage speaker linguistic behaviors related to aspects of core syntax may also be due to general resource limitations, such as memory constraints, that exert a larger influence in the non-dominant language. In a study on anaphor binding in heritage Korean, Kim (2007) found that heritage Korean speakers in both the U.S. and China showed a preference for local anaphor binding compared to long distance binding in heritage Korean. In a separate interpretation of these results, (Scontras et al., 2015) suggested that the preference for local anaphora binding in this study could be attributed to limitations in heritage language online syntactic computations that require more resources. In the words of Scontras and colleagues: “[g]iven that the heritage speaker is already performing the costly task of speaking in a less dominant language, the cost of resource-intensive operations explodes, sometimes to the point of totally obscuring the availability of the operation” (2015, p. 5).

Outside of the heritage language research that has examined interface phenomena, comparatively few studies have focused on online heritage language processing (e.g., Jegerski, Keating, & VanPatten, 2016; Keating, Jegerski, & VanPatten, 2016; Kim, 2005; Montrul, 2006; Montrul, Davidson, de la Fuente, & Foote, 2014; Moreno & Kutas, 2005; Sekerina & Trueswell, 2011). The findings from

\[\text{10}\] However, see Keating, Jegerski, and Van Patten (2016) for evidence of monolingual-like pronoun processing in real time for heritage Spanish speakers.
these studies generally indicate that various aspects of online language processing are qualitatively similar for heritage speakers and late bilinguals or monolinguals, but heritage speakers are typically slower. Montrul (2006) tested online processing of Spanish sentences with unaccusative and unergative verbs for heritage Spanish speakers and Spanish monolinguals and found overall no differences in syntactic knowledge or processing although, not unexpectedly, heritage speakers were slower in both languages compared to monolinguals (see Bialystok, Craik, Green, and Gollan (2009) for processing differences between monolinguals and bilinguals).

In line with these findings, Jegerski et al. (2016) tested parsing of ambiguous relative clause Spanish sentences and found that attachment preferences for heritage Spanish speakers patterned like those of Spanish monolinguals and Keating et al. (2016) examined the interpretation of null and overt pronouns in Spanish during online processing with a self-paced reading task and found only slight differences in referential interpretations between heritage Spanish speakers and Spanish monolinguals (notably, this finding contrasted earlier results obtained with offline measures in Keating et al. (2011)). Montrul et al. (2014) examined online processing of gender agreement in Spanish and found that heritage Spanish speakers, although somewhat slower and less accurate, patterned like late Spanish-English bilinguals in a task that did not require metalinguistic reflection. Using the event-related potential (ERP) technique, Moreno and Kutas (2005) found similar patterns of recognition of semantic anomaly but slower semantic integration during online Spanish sentence comprehension for heritage Spanish speakers compared to Spanish-dominant bilinguals. Finally, during an eye-tracking study with the visual world paradigm, Sekerina and Trueswell (2011) found slower processing of contrastiveness in Russian among heritage Russian speakers compared to Russian monolinguals and only subtle differences in their sensitivity to different contrastiveness cues.

As Sorace (2011) notes, a processing account (rather than a representational account) of bilinguals’ divergent performance involving interface phenomena is supported by several aspects of the empirical findings: “(a) bilingual-monolingual differences appear to be more quantitative than qualitative, (b) performance is affected by the characteristics of the task, and (c) much variation is attested both within and across individual speakers” (p. 20). The heritage language literature generally reports similar findings: (a) differences between heritage speakers and baseline groups are typically more quantitative
than qualitative, (b) heritage speakers show performance differences related to the type of experimental task, and (c) results typically show significant variation within and across individual heritage speakers.

Together, the evidence reviewed here suggests that real-time processing differences are likely to play an important role in shaping heritage language development and use. Given the hypothesized role of processing limitations both during real-time language use and in driving attrition of grammatical knowledge over time, it seems that much is to be gained by studying heritage language processing in real time. While the studies that have so far examined online heritage language processing have contributed significantly to our understanding of the forces shaping real-time heritage language production and comprehension, these studies have focused almost exclusively on processing limitations. Comparatively, little attention has been given to another well-established processing influence, namely cross-linguistic influence on processing. Before considering the possible role of dominant language influence on heritage language online processing, the next section summarizes key findings from offline heritage language studies that have been interpreted as evidence of cross-linguistic influence on grammatical representation in order to clarify where and how cross-linguistic influence on processing is likely to be observed.

Cross-Linguistic Influence

In comparison to experimental studies that have approached heritage language divergence and instability from the perspective of arrested development or attrition, fewer heritage language studies have focused on testing direct influence from the dominant language on the heritage language (e.g., Albirini & Benmamoun, 2014; Austin, Blume, & Sánchez, 2013; Cuza, 2013; Kim, Montrul, & Yoon, 2009, 2010; Montrul, 2010; Montrul, Foote, & Perpiñán, 2008b; Montrul & Ionin, 2010; Pascual y Cabo & Soler, 2015). Here, ‘direct influence’ refers to a form of dominant language influence in which specific grammatical properties of the heritage language can be unambiguously linked to specific grammatical properties of the dominant language (compare this to the idea of ‘indirect influence’ in which a heritage language feature is said to result from increased exposure to the dominant language but the feature itself cannot be linked to any specific grammatical property of the dominant language). Findings from most heritage language studies either leave open the role of direct cross-linguistic influence or make no mention of it as a
possible contributing factor. One likely reason that direct cross-linguistic influence has been understudied is that heritage language research has largely taken a DEFICIT perspective, focusing on grammatical areas where heritage speakers fail to show target-like sensitivity to grammatical features. Starting from this perspective, it is difficult to tell whether the absence of sensitivity to a grammatical feature, such as producing indicative verbal morphology in Spanish in a syntactic environment where the subjunctive is obligatory in baseline varieties, reflects the influence of dominant language knowledge, in this case the use of indicative morphology in a parallel grammatical environment in the dominant language, or whether this divergent behavior is unrelated to the specific properties of the dominant language, such as absence of mood as a morphosyntactic feature in the heritage language.

Given the difficulty in interpreting the absence of sensitivity to a grammatical feature in the heritage language, most claims of direct cross-linguistic influence have been based on positive evidence. One form of positive evidence indicating direct dominant language influence is the REINFORCEMENT of grammatical patterns that already exist in the heritage language and are shared with the dominant language, such as: increased use of English-like possessive constructions and extension of the English-like sound plural in heritage Arabic where the broken plural would be used by monolinguals (Albirini & Benmamoun, 2014); overuse of Dutch-like analytic genitive constructions instead of the construct state genitive among heritage Arabic speakers residing in the Netherlands (Boumans, 2006); and increased production of English-like dative constructions and reciprocal constructions in heritage Spanish (Carando, 2015).

A second, stronger type of positive evidence for direct influence from the dominant language is the presence of NOVEL features in the heritage language that parallel specific grammatical features of the dominant language. This type of influence has been reported in heritage language production, including use of (ungrammatical) English-like “two” + plural noun instead of dual inflectional morphology in heritage Arabic (Albirini & Benmamoun, 2014). More often, these effects have been observed in comprehension measures, including higher ratings for (ungrammatical) English-like subject-verb order in embedded wh-

11 A few studies have drawn conclusions that explicitly rule out the role of cross-linguistic influence (Hopp & Putnam, 2015; Polinsky, 2011). Hopp and Putnam (2015), for example, state that heritage German spoken among members of a language island in the U.S. does not reflect the wholesale adoption of English SVO basic word order, but they do suggest a more subtle effect of English influence.
questions in heritage Spanish (but limited production of these forms in an follow-up oral production task) (Cuza, 2013) and acceptance of (ungrammatical) English-like causative constructions in heritage Spanish (Higby, 2016; Higby et al., 2016). Most relevant to the present study, higher rates of acceptance of (ungrammatical) English-like preposition stranding in Spanish (but more restricted production of this structure in a written task) have also been reported among heritage Spanish speakers compared to late Spanish-English bilinguals, who categorically rejected these constructions (Depiante & Thompson, 2013; Pascual y Cabo & Soler, 2015).

Like the explanations for heritage language divergent linguistic behavior couched in terms of arrested development and attrition, the explanations that have been offered to account for evidence of direct cross-linguistic influence point to changes in heritage language grammatical REPRESENTATION. For instance, in explaining higher acceptance rates for Spanish preposition-stranding among heritage speakers who were exposed to English from birth (compared to heritage speakers exposed to English after age six), Pascual y Cabo and Soler (2015) argued that these individuals had developed a syntactic category in their Spanish grammar that licensed preposition stranding. Although these heritage speakers showed a preference for preposition pied-piping, the authors suggested that the syntactic category that licensed Spanish preposition stranding was a stable feature of their heritage language grammar. Given that the two heritage speaker groups in this study had similar Spanish proficiency and spoke the same Spanish dialect but differed in the age at which they were exposed to English, Pascual y Cabo and Soler concluded that age of exposure to English played the decisive role in the development of the grammatical feature that licenses preposition stranding in Spanish. Following this line of thinking, the authors concluded that the heritage speakers who were exposed to English after age 6 rejected Spanish preposition stranding like the late bilinguals tested in the study because the syntactic constraint that specifies pied-piping solidified before exposure to English began.

Similarly, Cuza (2013) interpreted the acceptance of (ungrammatical) subject-verb order in embedded Spanish interrogatives as evidence that core syntactic representations are susceptible to

12 While this hypothesis can explain higher ratings for preposition stranding, it does not straightforwardly account for significant differences in ratings between the pied-piped and preposition-stranded sentences that were observed in this study.
cross-linguistic influence, stating: “[t]hese results also suggest that the difficulties heritage speakers have do not necessarily stem from an interrupted development during childhood but rather from crosslinguistic influence from the dominant language. The participants’ performance in the oral task indicates that the syntactic mechanism for subject–verb inversion is in place, albeit permeated by crosslinguistic influence effects from the dominant L2” (p. 90). What is meant by “permeated by crosslinguistic influence” is not developed further in Cuza’s conclusion, however, the mechanism of cross-linguistic influence in Putnam and Sánchez (2013) model of heritage grammar suggests one way that cross-linguistic influence might operate.

Putnam and Sánchez (2013) proposed a generative model of heritage language grammar that attributes heritage language instability and divergence to influence from the dominant language at the level of formal feature value specification for heritage language lexical items. This model rests on two assumptions—the first is that linguistic knowledge consists of three sets of features that are associated with lexical items: formal features (FFs), which encode the grammatical properties of the lexical item; phonological features (PFs), which encode its phonological properties; and semantic features, which encode its semantic properties. The second assumption is that the activation level of a given FF value is determined by the frequency of exposure to lexical items that instantiate the FF value. Following these assumptions, cross-linguistic influence is the result of FF values from the dominant language becoming associated with lexical items from the heritage language. In this account, heritage language properties that show instability or divergence from baseline are the result of fluctuating activation levels between heritage language lexical items and competing FF values in the dominant and heritage languages. As heritage speakers process more input in the dominant language and less input in the heritage language, FF values that are specific to the dominant language may become linked to heritage language lexical items and these dominant language FF values may eventually replace the heritage language FF values altogether. In support of this model, Putnam and Sánchez cite findings from several previous studies focused on heritage language production as evidence of dissociation between heritage language lexical items and FF values and they suggest that evidence from L2 acquisition research provides further support for the idea that FF dissociation and remapping between languages is possible (2013, p. 492).
One crucial feature of the mechanism proposed in this model is that it can account for both divergent outcomes of heritage language acquisition and continual changes in the heritage language during adulthood in response to increased use of the dominant language. In this model, cross-linguistic influence from the dominant language occurs at the level of FF value association and activation, which allows for both transient influence from the dominant language during processing (in the form of competition between heritage language and dominant language FF values associated with a particular lexical item) as well as more permanent influence, in the case of complete dissociation between heritage language FFs values and lexical items and replacement with dominant language FF values.

Importantly, since the strength of feature activation is linked to the frequency with which the FF values are encountered in the input, this model can accommodate what appears on the surface to be instability in heritage language grammatical competence. According to Putnam and Sánchez, “…what fluctuates is not the grammar per se but the levels of activation of the lexicon and the strength of the association between functional, semantic, and PF features” (2013, p. 488). Additionally, “…the strength and directionality of the connections between lexical items in the two lexicons available to the bilingual individual are subject to change according to changes in the level of proficiency in the second language” (2013, p. 489). These key aspects of the mechanism of cross-linguistic influence can provide a unified account for several often cited but underexplored linguistic behaviors that have been widely reported in the heritage language literature: differences in performance between production and comprehension measures, less than fully acceptable ratings given to syntactic configurations that reflect dominant language influence within comprehension tasks noted above, and larger intra-individual ranges in performance for heritage speakers compared to speakers in the baseline comparison groups (e.g., Montrul, 2011). While findings related to differences in performance between individual heritage speakers have been attributed to divergent sets of grammatical knowledge resulting from differences in the conditions of heritage language acquisition, findings related to intra-speaker instability within a given grammatical area are less straightforwardly accounted for by explanations based on differences in grammatical representation. Given that these studies primarily employ offline metalinguistic tasks, which pose greater challenges for heritage speakers than for the comparison groups, it is possible to attribute some degree of the intra-individual variation to task effects (Montrul et al., 2014), however, this variation
may also reflect moment-to-moment differences in how heritage speakers access and deploy their linguistic knowledge in real time.

The literature reviewed in this section suggests that heritage speakers’ production and comprehension of their heritage language is affected by direct influence from their dominant language. Although it is generally claimed that core syntax is the least susceptible domain to cross-linguistic influence, this is precisely the domain where positive evidence for direct influence from the dominant language can be most readily observed. While some explanations of cross-linguistic influence have pointed to changes in heritage language grammatical representation as the source of divergent heritage language behaviors, these explanations cannot account for other aspects of heritage speakers’ performance in experimental tasks. In contrast, the model of heritage language grammar put forth in Putnam and Sánchez (2013) is based on a mechanism of cross-linguistic influence that is driven by fluctuations between heritage language lexical items and FFs in the heritage and dominant language, which can accommodate both stable and transient changes in heritage language behaviors. This model not only provides a unified explanation for several well-known characteristics of heritage speakers’ linguistic behaviors—it also offers a concept of cross-linguistic influence that can be empirically tested.

CONCLUSION

The vast heritage language research that has been carried out in the past two decades has been crucial in mapping grammatical areas that are susceptible to change, as well as identifying how the context of heritage and dominant language development shapes the trajectory and ultimate outcome of heritage language acquisition, and outlining the types of high level processes that are most likely to contribute to divergent outcomes. At the same time, few models have been offered to explain the mechanisms that underlie the processes of change characterized in terms of attrition, arrested development, and cross-linguistic influence. One notable exception is the model outlined in Putnam and Sánchez (2013) which explains heritage language instability and change in terms of fluctuating activation
levels between heritage language lexical items and competing grammatical features and constraints instantiated in the dominant and heritage languages.\textsuperscript{13}

While the few studies that have examined heritage language processing have focused primarily on online processing limitations, no studies have directly tested another likely source of heritage language differences that is predicted by Putnam and Sánchez’s (2013) model: dominant language influence during heritage language online processing. While it is difficult to test cross-linguistic influence on heritage language morphosyntactic processing, the basic mechanism of Putnam and Sánchez’s model can be straightforwardly tested in the domain of syntax. To date, the findings from the few studies that have examined heritage language syntactic processing suggest qualitative processing similarities between heritage speakers and late bilinguals but some quantitative differences. Beyond the general finding that has been reported in the literature, that heritage speakers possess more limited online processing capacity in the heritage language, we know little about heritage language processing strategies and we are far from fully understanding how processing procedures and representational knowledge in the heritage and dominant language interact with one another.

Considering the characteristics of findings from offline studies that have been interpreted as direct dominant language influence, it remains unclear whether the observed effects should be attributed to differences in heritage language representation or processing. While Pascual y Cabo and Soler (2015) suggested that heritage Spanish speakers who were exposed to English from birth were more accepting of Spanish preposition stranding due to the development of a grammatical feature that licensed this structure in Spanish, their results are equally compatible with an explanation that holds that these individuals’ Spanish grammars are representationally similar to those of sequential heritage speakers and late bilinguals in the study and the observed differences are instead due to differences in how their grammatical knowledge is accessed and deployed online. The offline experimental methods that have been used in heritage language studies to date are not adequate to differentiate between these

\textsuperscript{13} In similar later proposals, Polinsky (2016), Scontras et al. (2015), and Scontras, Polinsky, and Fuchs (2018) have suggested that some differences in heritage languages can be explained in terms of restructuring functional feature categories (such as number and gender) in the heritage language. For example, number and gender features may be bundled in their heritage grammar (for reasons of representational economy), whereas they have distinct syntactic projections in a monolingual grammar (Scontras et al., 2015).
explanations. The mechanism proposed in Putnam and Sánchez (2013) makes specific testable predictions about how activation of grammatical features or constraints in the dominant language should influence heritage language processing, yet, these predictions have not been tested directly.

The next chapter reviews the evidence from sentence processing research on non-heritage-speaker bilinguals that provides strong support for the idea that moment-to-moment fluctuations in the influence of the dominant language on heritage language processing may account for some of the findings noted above. Based on these findings, the present study was conducted to probe cross-linguistic influence from the dominant language on real-time syntactic processing in the heritage language. The next chapter will address key tenets of bilingual sentence processing, specifically when and where L2-on-L1 processing influence occurs, and then outline an experimental approach that offers a window to observe the effects of cross-linguistic influence on syntactic processing in real time: CROSS-LINGUISTIC STRUCTURAL PRIMING.
CHAPTER 3: CROSS-LINGUISTIC INFLUENCE IN BILINGUAL PROCESSING

INTRODUCTION

The present study investigates whether dominant language influence on heritage language processing can explain some common properties of heritage languages that have been reported in the findings of experimental research based on offline methods. This section examines current research on bilingual processing pertaining to this question. The first section reviews research that has suggested a significant degree of ‘overlap’ or interaction between a bilingual’s languages and concludes with a focus on the processes of cross-linguistic activation and inhibition. Next, pertinent findings from the bilingual syntactic processing literature are summarized along with research that has shown evidence that L1 processing strategies are susceptible to influence from a language learned in adulthood. This section concludes by discussing how this research has shown cross-linguistic influence both in the form of competition between L1 and L2 syntactic processing strategies and reinforcement between L1 and L2 syntactic processing and how these findings bear on the questions of where and how heritage language processing is likely to be influenced by the dominant language. The final section of this chapter summarizes current findings related to cross-linguistic structural priming, which has provided most of the evidence of reinforcement during bilingual syntactic processing and is the primary method used in the present study.

LANGUAGE INTEGRATION

The vast majority of evidence that has indicated integration between a bilingual’s languages has come from psycholinguistic studies of language use in real time.\(^4\) Although psycholinguistic research on bilingualism has a relatively short history compared to psycholinguistic research on monolinguals, empirical studies of cross-linguistic influence among various bilingual populations have provided evidence for a significant degree of integration between a bilingual’s two languages at all levels of linguistic representation. (For overviews, see Desmet and Duyck (2007), Hernández, Fernández, and Aznar-Besé

\(^{14}\) See also Abutalebi, Cappa, and Perani (2005), Kotz (2009), van Hueven, Schriefers, Dijkstra, Hagoort, and Hagoort (2008), and Weber and Indefrey (2009) for brain imaging studies that have examined structural overlap and integration between a bilingual’s two languages.
This research suggests that a bilingual does not have two entirely separate language systems that can be accessed selectively, providing empirical support for the widely known concept that a bilingual is more than the sum of two monolinguals (Grosjean, 1989).

Research on the integration of the bilingual lexicon has received by far the most attention. At the level of the word, integration has been shown for both phonological and semantic representation (Pavlenko, 2009). Findings from studies of phonological integration show that exposure to a word in a bilingual’s L1 that shares certain phonological feature with a given word in their L2 will result in faster visual recognition of the L2 word (Brysbaert, Van Dyck, & Van de Poel, 1999) and, more relevant for the present study, this influence also occurs from the L2 to the L1 (Van Wijnendaele & Brysbaert, 2002). Faster recognition of these words has been interpreted as evidence of non-selective lexical access—i.e., when performing a task in one language, lexical items are activated in both of a bilingual’s languages. Hearing a word in one language has also been found to activate words in the other language that share phonological features but have unrelated meanings, though this effect is not always equivalent in both directions: in some studies, activation from L2 to L1 was found to be stronger than activation from L1 to L2 (e.g., Spivey & Marian, 1999; Weber & Cutler, 2004) but differences in the opposite direction have also been reported (e.g., Marian & Spivey, 2003) as have comparable effect sizes in both directions (e.g., Van Wijnendaele & Brysbaert, 2002). These findings have been interpreted as evidence that during production and comprehension in either the L1 or L2, bilinguals access lexical items in the other language that have similar phonological representations.

Research on semantic integration at the word level has similarly found evidence that a bilingual’s L1 and L2 access a shared conceptual/semantic system (Francis, 2005). Like the findings related to phonological integration, this research shows that exposure to words in one language influences activation of semantically related words in the other language. Perhaps unsurprisingly, during comprehension of words in the L2, proficient bilinguals have been found to activate their L1 translation equivalents (see Kroll and Dussias (2013) and references therein). More unexpected are findings that have shown recognition of a word in the L2 to be faster after exposure to a semantically-related word in the L1, although the size of this effect is somewhat smaller compared to the effect of exposure to a
semantically-related word within the L1 (Desmet & Duyck, 2007). Most relevant to the present study, experiments that have been conducted in only one of a bilingual’s languages still found significant influence from the other language. Investigating the effects of combined phonological and semantic overlap in a study of Dutch-English-French trilinguals, van Hell and Dijkstra (2002) found that even when the experiment was conducted entirely in Dutch—the first and dominant language for all subjects—Dutch words that were cognates with English or French words were recognized faster compared to non-cognate Dutch words. Importantly, this study also showed that this effect only occurred for participants who had higher proficiency in the second and third languages, underscoring the importance of proficiency in determining the extend of cross-linguistic influence during lexical processing.15

Activation and Inhibition

While most of the studies mentioned above have involved tasks in which target words were presented in isolation, evidence of bilingual lexical integration has also been found in studies where the target words appeared in sentences (Desmet & Duyck, 2007; Kroll & Dussias, 2013). These findings suggest that when a bilingual is processing written or spoken sentences in one language—even their L1—both of their languages are activated.16 Findings that both of a bilingual’s languages are active during experiments that involve recognition of sentence-embedded words from a single language, which act as a strong bias for lexical search (Desmet & Duyck, 2007), even when the experimental task does not require use of the other language at all, provide evidence that bilinguals may not be able to completely inhibit either of their languages while using the other (Dijkstra, 2005; Kroll & Dussias, 2013; van Hueven et al., 2008). Similar results have also been found during bilingual production (Hatzidaki et al., 2011). As Kroll and Dussias state: “[T]he results of many studies that examine the recognition of written words and the comprehension of spoken words converge on the conclusion that it is virtually impossible for bilinguals to

15 Similar influence from the language not in use has also been found for tasks presented in only one language that required subjects to focus on the meaning of the word, rather than simply determining whether or not the stimulus was a word (Kroll & Dussias, 2013) and studies that have used electrophysiological measures (Midgley, Holcomb, & Grainger, 2009).

16 Findings from these behavioral studies that suggest the language not in use remains active during sentence processing in the other language are further supported by results from ERP studies that have investigated language switching (Moreno, Federmeier, & Kutas, 2002; Moreno, Rodriguez-Fornells, & Laine, 2008). The relative ease with which code switching is processed has been taken to indicate that while parsing a sentence in one language, a bilingual’s other language is active.
ignore the language not in use...[c]ritically, even highly proficient bilinguals who are able to process each language quite skillfully demonstrate parallel activation of both languages” (2013, pp. 217–218).

While the research summarized above has shown clear evidence of parallel language activation, another line of research has approached bilingual language integration from the other direction, seeking to understand how bilinguals inhibit the language not in use (Abutalebi & Green, 2008; Green, 1986, 1998; Kroll & Sunderman, 2003). The typical measure for this research is SWITCHING COST. In production studies with late bilinguals, this research has shown a larger cognitive cost when switching from L2 into L1 compared to switching from L1 to L2, which has been interpreted as evidence that initial suppression of the L1 required a greater amount of attentional resources compared to suppression of the L2 (Meuter & Allport, 1999; Rodriguez-Fornells, De Diego Balaguer, & Münte, 2006; but see Costa and Santesteban (2004) for evidence of symmetrical inhibition costs for highly proficient bilinguals). While these studies have typically focused on language inhibition during production, it is not clear to what extent similar inhibition mechanisms play a role during comprehension. Desmet and Duyck state: “[i]n recognition, a bilingual is confronted with input in a given language, and there is no compelling need for an early language selection mechanism” (2007, p. 188). However, as the research reviewed above shows, it is not possible to completely inhibit the language not in use during comprehension, which suggests that the issue of language selection and inhibition during comprehension may not be trivial. This is especially true for heritage speakers, who generally report significant differences in dominance and proficiency between their L1 and L2 and, based on the above evidence, are likely to experience greater difficulties in inhibiting their dominant language during use of the heritage language.

**BILINGUAL SYNTACTIC PROCESSING**

Similar to the findings of language integration and co-activation during word-level processing, evidence of integration and cross-linguistic activation has also been found for sentence-level processing, although this area has been subject to far less empirical testing. While a significant amount of research on bilingual syntactic processing has been conducted in the past couple decades (see Dussias, Dietrich, 17 This has been attributed in part to the difficulty of designing experimental tasks to show how the activation of a syntactic structure in one language can influence the activation of a syntactic structure in another language.

17 This has been attributed in part to the difficulty of designing experimental tasks to show how the activation of a syntactic structure in one language can influence the activation of a syntactic structure in another language.
and Villegas (2015) for an overview), this work has focused mainly on late L2 learners and has sought to address the question of whether L2 syntactic processing for these individuals is fundamentally different from monolingual syntactic processing (e.g., Clahsen & Felser, 2006; Frenck-Mestre & Pynte, 1997; see Gertken (2013) for a recent and comprehensive review of this literature). While the question of whether or not L2 syntactic processing relies on fundamentally different mechanisms from those involved in L1 syntactic processing is beyond the scope of the current study, research in this area highlights two experimental paradigms that have been successfully used to study how specific properties of one of a bilingual’s languages influence syntactic processing in their other language. These paradigms address two different sides of cross-linguistic influence: COMPETITION and REINFORCEMENT. Here, the term competition refers to cross-linguistic influence in which a syntactic processing strategy in one of a bilingual’s languages becomes less favored because an alternative processing strategy exists in the other language for the same structure; reinforcement is meant to be understood in a purely descriptive sense as the opposite of competition, i.e., cross-linguistic influence in which processing strategies that are the same for a syntactic structure that exists in a bilingual’s two languages are more favored.

**Competition**

One possible outcome of cross-linguistic influence on syntactic processing is that processing strategies from one language may interfere with syntactic processing of the other language. The vast majority of studies concerned with cross-linguistic influence during bilingual syntactic processing have addressed this possibility by focusing on syntactic properties that differ between a bilingual’s first and second language in order to determine how syntactic processing strategies are selected between the alternative options in each of a bilingual’s languages. Many of these studies have focused on relative clause (RC) attachment preferences and the well-documented differences among languages (Cuetos, Mitchell, & Corley, 1996) in order to determine whether, for bilinguals who speak two languages that exhibit opposite RC attachment preferences, the RC attachment preferences in their L1 influence RC attachment preferences in their L2 (for studies involving L2 English/L1 Spanish and L2 Spanish/L1 English see Dussias (2001, 2003) and Fernández (2000, 2003); for L2 Greek/L1 German, L1 Russian, and L1 Spanish see Papadopoulou and Clahsen (2003); for L2 English/L1 Japanese see Omaki (2005); for L2 English/L1 Greek and L1 German see Felser, Roberts, Marinis, and Gross (2003)). While the
research focused on RC parsing preferences in L2 has produced mixed results\textsuperscript{18}, the extension of this paradigm to investigating the influence of L2 on L1 RC parsing preferences in two studies is relevant to the present study.

Dussias (2004) examined the impact of L2 exposure on L1 syntactic processing by analyzing eye-movement data for Spanish monolinguals and proficient L1 Spanish-L2 English bilinguals while they read Spanish sentences with locally ambiguous RCs, like (1a) and (1b). While English monolinguals typically parse locally ambiguous RCs in the English equivalents of sentences like (1a) and (1b) (*que estaba enferma desde hacía tiempo* “who had been ill for a while”) as modifying the local noun phrase (*la niñera* “the babysitter” in (1a), *el criado* “the servant” in (1b)), Spanish monolinguals typically favor the non-local noun phrase (*el hermano* “the brother” in (1a), *la hermana* “the sister” in (1b)) (Carreiras, Salillas, & Barber, 2004; Cuetos & Mitchell, 1988).

1. a. *El policía arrestó al hermano de la niñera que estaba enferma desde hacía tiempo.*

   “The police arrested the brother (masc) of the babysitter (fem) who had been ill (fem) for a while.”

b. *El policía arrestó a la hermana del criado que estaba enferma desde hacía tiempo.*

   “The police arrested the sister (fem) of the servant (masc) who had been ill (fem) for a while.”

The results of this study showed that the Spanish-English bilinguals favored local attachment of the RC (as in English) over non-local attachment of the RC (as in Spanish), which was indicated by

\textsuperscript{18} The findings from this body of work show both similarities and differences between monolingual and L2 sentence processing during comprehension. Some studies have found inconsistencies in L2 processing (e.g., Papadopoulou and Clahsen (2003) found no preferences in L2 Greek RC processing in either online or offline tasks for L1 speakers of German, Russian, and Spanish (which all show NP1 preference)). Omaki (2005) also found inconsistencies in L2 English RC attachment among L1 Japanese speakers when analyzed as a group. However, individual analyses revealed more consistency within speakers, with some showing transfer of preferences from L1 while others showed native-like preferences in L2 processing. To account for empirical differences in L2 processing Clahsen and Felsner (2006) postulated the shallow-structure hypothesis, which claims that adult L2 learner parsing strategies are guided exclusively by lexical, semantic, and pragmatic information and cannot make use of the syntactic cues that are central to monolingual syntactic processing. Thus, the syntactic representations computed during L2 syntactic processing are comparatively ‘shallow’ and less detailed than the syntactic structures generated during L1 syntactic processing. In a summary of this vast literature, Gertken (2013) concludes that most studies show that L2 learners process L2 sentence incrementally, like L1 users, but they may differ from L1 users in that they are sensitive to different cues or use different strategies and their processing is modulated by L2 proficiency and experience.
longer reading times at the RC adjective (enferma “sick”) when it disambiguated RC attachment via gender agreement towards the non-local NP (la hermana “the sister” in (1b)) compared to reading times when the RC adjective disambiguated attachment toward the local NP (la niñera “the babysitter” in (1a)). In contrast, the Spanish monolinguals favored non-local attachment of the RC, which was indicated by longer reading times at the RC adjective (enferma “sick”) when it forced RC attachment to the local NP (la niñera “the babysitter” in (1a)) compared to when it forced attachment with the non-local NP (la hermana “the sister” in (1b)).

Dussias interpreted these results as evidence that that daily exposure to English for the Spanish-English bilinguals had shifted the RC parsing preferences for these subjects. Dussias stated that this finding was surprising given that these bilinguals had been living in an English-speaking environment for 3.7 years on average and it is generally thought that L1 attrition typically sets in only following extensive exposure to the L2 (e.g., after 10 years of L2 immersion). The results were also interpreted as reflecting a change in the tacit knowledge of the bilingual participants, rather than difficulty in syntactic processing per se since there was no evidence of reading disfluency, which would indicate that processing was affected.

In a follow-up to this study, Dussias and Sagarra (2007) confirmed the influence of L2 exposure on shifting L1 RC parsing preferences. This study, which used the same stimuli from Dussias (2004), tested Spanish RC attachment preferences between two sets of highly proficient Spanish-English bilinguals who differed in their exposure to English in an immersive setting. The results indicated that the Spanish-English bilinguals who had been immersed in an English-speaking environment for an average of 7.1 years and were living in the U.S. at the time of testing showed English-like (local) RC attachment preferences while the Spanish-English bilinguals who had been immersed in English for an average of 8.5 months and were living in Spain at the time of testing showed Spanish-like (non-local) RC attachment preferences.

Together, the findings from these studies have been interpreted as evidence that bilingual L1 syntactic processing is sensitive to fluctuations in daily exposure to the L2. However, there is some evidence that heritage Spanish speakers may not be so susceptible to similar influence from extensive exposure to L2 English. In one of the few studies that has examined heritage language syntactic processing, Jegerski et al. (2016) found that heritage Spanish speakers who had been living in an
English-dominant environment for the majority of their lives showed Spanish-like (non-local) RC attachment preferences for the same type of RC sentences tested in Dussias (2004) and Dussias and Sagarra (2007). In interpreting these results, Jegerski and colleagues suggested that the age of onset of bilingualism may be responsible for the findings. Unlike the late Spanish-English bilinguals who were tested in Dussias (2004) and Dussias and Sagarra (2007), the heritage Spanish speakers tested in Jegerski et al.’s (2016) study were simultaneous or early sequential bilinguals who were exposed to English by age five. While this explanation is sensible given the differences in subjects’ L2 exposure between these studies, whether age of L2 exposure is solely responsible for the differences in L1 syntactic processing between these studies remains an open question.

The research reviewed in this section has focused on how the particular features of syntactic processing in one language can begin to influence processing of similar syntactic structures in the other language. The findings show that L1 syntactic processing strategies are malleable even in adulthood and the extent to which cross-linguistic influence from L2 can shape L1 syntactic processing may be determined by age and amount of exposure to L2. Approaching questions related to bilingual syntactic integration from another angle, the research reviewed next has focused on determining whether syntactic properties that are similar in a bilingual’s two languages share one underlying representation by testing the reinforcement of syntactic processing for grammatical structures that are shared between the L1 and L2. Findings from this approach are important to understanding the level at which bilingual syntactic integration occurs. While the findings related to RC attachment suggested that bilingual syntactic processing can be influenced when it comes to competing preferences between L1 and L2 for ambiguous structures (e.g., whether to attach the RC to the local or non-local NP) the research summarized in the next section indicates that core syntactic processing procedures are also susceptible to similar influence.

Reinforcement

The research summarized in this section has focused on determining to what extent syntactic knowledge and processing routines are shared between a bilingual’s two languages. This research is similar to the studies of bilingual lexical integration discussed earlier in this chapter in that the evidence has come from experimental paradigms that involve activating a syntactic representation or processing routine in one language and measuring how that activation affects syntactic processing of a parallel
structure in the other language. This experimental paradigm is referred to as **CROSS-LINGUISTIC STRUCTURAL PRIMING**. This section reviews two early cross-linguistic structural priming studies that found evidence of syntactic overlap or integration between a bilingual’s languages and concludes by summarizing a model that has been developed to account for cross-linguistic structural priming effects in terms of activation of shared syntactic representations.

Experiments based on the cross-linguistic structural priming paradigm have found strong evidence of overlap or integration at the level of syntax. These studies show that, among bilinguals, hearing or using a syntactic structure in one language promotes its use in the other language. Cross-linguistic structural priming was first used by Loebell and Bock (2003) to test whether, among fluent German-English bilinguals who had been immersed in English for 2–36 years at the time of testing, production of certain dative and transitive sentence constructions in one language would increase the likelihood that these bilinguals would produce the same structure in the other language to describe an unrelated picture. The results of this study showed that production of a prepositional-object (PO) dative construction (as in (2a–b)) or double-object (DO) dative construction (as in (3a–b)) in either L1 German or L2 English increased the likelihood that the parallel structure would be used in a subsequent description of an unrelated picture.

2. a. *The boy sent a letter to his pen-pal.*
   b. *Der Junge schickte einen Brief an seinen Brieffreund.*

   “The boy sent a letter to his pen-pal.”

3. a. *The boy sent his pen-pal a letter.*
   b. *Der Junge schickte seinem Brieffreund einen Brief.*

   “The boy sent his pen-pal a letter.”

For the transitive sentences, the results showed that production of an active construction (as in (4a–b)) in either L1 German or L2 English led to greater use of the active structure in the subsequent description of an unrelated picture, but this effect was not statistically significant. In the case of the
passive structure (as in (5a–b)), production of a sentence with this construction in either language did not significantly affect the construction used in the subsequent picture description.

4. a. *The janitor cleans the floors daily.*
   b. *Der Hausmeister reinigt die Böden täglich.*
      “The janitor cleans the floors daily.”

5. a. *The floors are cleaned daily by the janitor.*
      “The floors are daily by the janitor cleaned.”

While there were subtle non-significant differences in the size of the priming effect between PO and DO constructions and from L1 German to L2 English and vice versa, beyond the significant effect of cross-linguistic priming for these structures, the major finding was the absence of priming for active and passive constructions. While Loebell and Bock attributed the lack of significant priming effects for the active constructions to the tendency for structural priming to have less influence on a high-frequency constructions compared to lower frequency constructions (Bock & Griffin, 2000), the absence of priming for passive constructions was explained by the difference in surface word order between the passives in German and English. Since the main verb past participle appeared in sentence-final position in the German passives (as in (5b)) unlike in the English passives, Loebell and Bock reasoned that the activation of structure building procedures associated with a given syntactic construction in one of bilingual’s languages would only promote use of the analogous construction in the other language if the two constructions also shared the same surface word order.

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19 In these German passive sentences, the past participle of the main verb (*gereinigt* “cleaned”) appeared in sentence-final position.

20 The priming effect was somewhat stronger for the DO construction compared to the PO construction. More PO datives were produced in English than in German, but more DO datives were produced in German than in English. And there was a non-significant trend for more priming from L1 German to L2 English than from L2 English to L1 German.

21 It has been shown elsewhere that priming typically does not occur where there are word order differences between analogous structures in the two languages (e.g., Bernolet, Hartsuiker, & Pickering, 2007 but there is some evidence to the contrary (see Chen, Jia, Wang, Dunlap, & Shin, 2013; Desmet & Declercq, 2006; Shin & Christianson, 2009; Song & Do, 2018).
While Loebell and Bock interpreted their findings in terms of the activation of shared structure building procedures involved in producing a given syntactic construction, other researchers have interpreted cross-linguistic priming effects as evidence of sharing at the level of syntactic representation. In this framework, Hartsuiker et al. (2004) tested the integration of syntactic knowledge between L1 Spanish and L2 English among late Spanish-English bilinguals. In this study, Hartsuiker and colleagues hypothesized that structures that are common to both languages (e.g., the passive structure in Spanish and English) shared a single abstract syntactic representation. To test this hypothesis, the authors conducted a cross-linguistic structural priming experiment in which a confederate and research subjects played a game that involved one person describing the image on a card and the other person finding the matching card (Branigan, Pickering, & Cleland, 2000). While the confederate spoke exclusively in Spanish (the L1 for both participants) during the task, the subject was instructed to speak exclusively in English (the L2 for both participants).

The results of the study showed that subjects were more likely to describe a picture in L2 English using a passive structure after the confederate produced a description using the passive in L1 Spanish (as in (6b)) during the previous turn, compared to when the confederate produced an active (as in (6a)) or intransitive sentence (as in (6c)). However, after hearing either an active Spanish sentence or a sentence with object-verb-subject (OVS) order (as in (6d)), subjects were not more likely to produce these constructions in L2 English.

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22 The Spanish-English bilinguals tested in Hartsuiker et al. (2004) had moderate to high proficiency in English and had been living in an English-speaking environment for 2 months–7 years at the time of testing (average of 22 months).

23 In contrast to Loebell and Bock’s study, in which subjects first repeated a given sentence in one language (L1 German or L2 English) aloud and then produced a novel sentence in the other language (priming from production to production), the subjects in Hartsuiker et al.’s study first heard a sentence in L1 Spanish and then produced a novel sentence in L2 English (priming from comprehension to production).

24 The verb to be used in the description was printed on each of the subject’s cards. Importantly, this verb was not related in meaning or form to the verb used by the confederate in the prime sentence.

“The taxi chases the truck.”

b. *El camión es perseguido por el taxi.*

“The truck is chased by the taxi.”

c. *El taxi acelera.*

“The taxi accelerates.”

d. *El camión lo persigue un taxi.*

“The truck [chasee] it chases a taxi [chaser].”

To interpret these results, Hartsuiker and colleagues proposed a model based on Pickering and Branigan’s (1998) model of lexical representation in which syntactic information, such as the types of arguments a verb can take, are encoded at a level of lexical representation called the LEMMA STRATUM. In this model, combinatorial nodes, which specify particular syntactic constructions (such as the passive construction), are shared between all lemma that can appear in that syntactic construction. In their extension of this model, Hartsuiker and colleagues propose that for syntactic constructions that occur in both of a bilingual’s languages (e.g., the passive in Spanish and English) there is a single combinatorial node specifying this construction shared by both languages. As verbs lemmas in Spanish and English that can appear in the passive are connected to the same combinatorial node specifying this construction, activation of this combinatorial node upon hearing a Spanish passive sentence renders this structure more readily available while processing English verbs that are connected to the same combinatorial node.

The important feature of Hartsuiker’s and colleagues’ interpretation is that cross-linguistic structural priming reflects the activation of a level of syntactic representation that is shared between a bilingual’s two languages (the combinatorial nodes). In contrast, Loebell and Bock interpreted cross-linguistic structural priming as a reflection of the activation of structure building processes associated with a given syntactic construction. Although it is difficult to distinguish empirically between these competing accounts (shared representation vs. shared structure building procedures), the important common finding is that for bilinguals, using a particular syntactic construction during production or comprehension in one language can reinforce its subsequent use in the other language. In the next section, the particulars of this cross-linguistic influence on syntax will be considered in more detail.
CROSS-LINGUISTIC STRUCTURAL PRIMING

Since Loebell and Bock’s and Hartsuiker and colleague’s pioneering studies, variations of the cross-linguistic structural priming paradigm have successfully been used to uncover cross-linguistic overlap or integration for numerous syntactic structures and language pairs, including: PO/DO constructions for Spanish-English (Carando, 2015; Meijer & Fox Tree, 2003), Dutch-English (Salamoura & Williams, 2006; Schoonbaert, Hartsuiker, & Pickering, 2007), Greek-English (Salamoura & Williams, 2007), Korean-English (Shin & Christianson, 2009), and Swedish-English bilinguals (Kantola & van Gompel, 2011); active/passive constructions for Spanish-English (Carando, 2015), Dutch-English (Bernolet, Hartsuiker, & Pickering, 2009), Chinese-English (Chen et al., 2013), and German-English bilinguals (Weber & Indefrey, 2009); RC attachment for Dutch-English (Desmet & Declercq, 2006) and English-German bilinguals (Kidd, Tennant, & Nitschke, 2015); RC/adjectival modifiers for Dutch-English and Dutch-German bilinguals (Bernolet et al., 2007); and reciprocal constructions for Spanish-English bilinguals (Carando, 2015).

Increased interest in cross-linguistic structural priming in recent years is owed to its ability to index psycholinguistic processes that have previously undergone little or no empirical testing due to a lack of adequate experimental measures. Cross-linguistic structural priming studies have played an important role in advancing theoretical models of bilingual syntax and syntactic processing. To understand how the findings with this method have been used to support these ideas, it is first necessary to understand the mechanisms and assumptions of cross-linguistic structural priming. Although the present study tests cross-linguistic structural priming during comprehension, due to the dearth of empirical studies that have examined cross-linguistic priming during comprehension (but see Kidd et al. (2015)), the literature review will necessarily focus on priming during comprehension in monolinguals and priming during production in bilinguals. This section starts with a brief introduction to the structural priming paradigm, followed by a summary of the factors known to influence cross-linguistic structural priming. Before concluding this chapter, the discussion will outline two prominent theories of structural priming, followed by a new area of research that is relevant to the present study: priming grammatical innovations.
A Short Introduction to Structural Priming

Structural priming denotes the phenomenon in which exposure to a particular linguistic structure leads to more frequent production of that structure or facilitates processing of parallel structures during comprehension (Bock, 1986; Pickering & Ferreira, 2008). This phenomenon is illustrated in Bock’s (1986) seminal work investigating structural priming for English active/passive sentences and DO/PO dative sentences. In one experiment in this study, participants were instructed to repeat sentences with active (exemplified in (7a)) or passive structures (exemplified in (7b)) and then described semantically unrelated pictures.

7. a. One of the fans punched the referee.
   b. The referee was punched by one of the fans.

Subjects showed a statistically significant tendency to describe the target pictures using the same structure that they just said aloud—if they repeated a sentence with passive structure, they tended to describe the picture with a passive sentence, and if they repeated a sentence with active structure, they tended to describe the picture with an active sentence. Since Bock’s (1986) study, over 100 investigations of structural priming have been published, which have shown that structural priming occurs following both the production and comprehension of a given syntactic structure and, similarly, the resulting influence affects both language production and comprehension (Pickering & Ferreira, 2008). Priming effects have been elicited across languages and linguistic structures using a variety of experimental paradigms and the cumulative evidence suggests that these effects result from cognitive processes operating on abstract syntactic knowledge similar to a phrase structure grammar, defined in terms of word classes (e.g., noun, verb), phrasal constituents (e.g., noun phrase (NP), verb phrase (VP)), and transformational rules (e.g., VP → verb NP) (Pickering & Ferreira, 2008). Furthermore, priming is thought to operate on local structural relations, since some studies have shown that differences between prime and target sentences with

25 Levelt and Kelter (1982) performed the first priming experiment, in which they called Dutch shop keepers and asked what time their store closed using two different forms of the question: either with a preposition om “at” as in Om hoe laat gaat uw winkel dicht? “At what time does your shop close?” or without, as in Hoe laat gaat uw winkel dicht? “What time does your shop close?”. They noted that shopkeepers tended to reply with or without the preposition following the structure of the question, e.g., (Om) vijf uur. “(At) five o’clock.”
regards to the internal structure of NPs or modification of NPs with an RC or the location of the NP in a subordinate or main clause do not reduce priming effects (Branigan, Pickering, McLean, & Stewart, 2006; Fox Tree & Meijer, 1999; Pickering & Branigan, 1998).

**Priming in Production and Comprehension**

In studies of structural priming during language production, subjects first repeat the prime structure aloud (e.g., Bock, 1986) or comprehend a sentence containing the prime structure (e.g., Bock, Dell, Chang, & Onishi, 2007; Branigan, Pickering, & Cleland, 2000; Cleland & Pickering, 2003; Potter & Lombardi, 1998; van Gompel, Pickering, Pearson, & Jacob, 2006) and are then prompted to produce a novel sentence. In this design, the measure of priming is how frequently the subject produces a novel sentence that is structurally identical to the prime sentence.

In studies of structural priming during language comprehension, the measure of priming is dependent on the experimental paradigm that is used. Typically, testing structural priming during comprehension is limited to syntactic constructions that are structurally ambiguous (e.g., ambiguous RC attachment) or a priori difficult to processes. In both cases, the priming effect is measured at the point during syntactic processing where the processing difficulty is expected to occur. The effect of structural priming on syntactic processing during comprehension for several syntactic structures has been studied using a variety of experimental measures that are sensitive to processing difficulty, including ERP, eye tracking, and self-paced reading.

In comprehension priming studies using ERP, the priming effect is operationalized as a reduction in the amplitude of the ERP component at the point of complexity or disambiguation in the target sentence (usually a P600 that is reduced following a prime) in prime trials compared to control trials. ERP has been used to measure priming effects for reduced-relative/main-clause ambiguities (Ledoux, Traxler, & Swaab, 2007; Tooley, Swaab, Boudewyn, Zirnstein, & Traxler, 2014; Tooley, Traxler, & Swaab, 2009) and prepositional phrase attachment ambiguities (Boudewyn, Zirnstein, Swaab, & Traxler, 2014). In

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26 This is similar to the design used in Dussias (2004) and Dussias and Sagarrá (2007) to test RC attachment preferences in Spanish. In these studies, processing difficulty at the disambiguating RC adjective revealed whether subjects had parsed the locally-ambiguous RC as modifying the local or non-local NP.
priming studies using eye tracking and self-paced reading, the priming effect is operationalized as a reduction in reading time at the point of complexity or disambiguation in the target sentence following a prime. In reading studies, eye tracking has been used to measure structural priming during comprehension for prepositional phrase attachment ambiguities (Boudewyn, Zirnstein, Swaab, & Traxler, 2014; Traxler, 2008a, 2008b) and reduced-relative/main-clause ambiguities (Tooley et al., 2014; Tooley et al., 2009; Traxler & Tooley, 2008; Traxler, Tooley, & Pickering, 2014) and self-paced reading has also been successfully used but to a lesser extent (e.g., Traxler & Tooley, 2008). A few methods, including picture matching tasks (Branigan, Pickering, & McLean, 2005) and eye tracking with the visual world paradigm (Arai, van Gompel, & Scheepers, 2007; Carminati, van Gompel, Scheepers, & Arai, 2008; Scheepers & Crocker, 2004; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Thothathiri & Snedeker, 2008a, 2008b) have also been successfully used to measure structural priming during comprehension for syntactic structures that are not a priori difficult to process (e.g., dative alternations and prepositional phrase attachment).

The effects of structural priming in comprehension have sometimes been found to be weaker than the effects obtained in production, which has led some researchers to suggest that priming in production and priming in comprehension may involve different mechanisms or levels of representation (Tooley & Traxler, 2010). However, studies that have found structural priming to occur from production to comprehension and vice versa (e.g., Cleland & Pickering, 2003; Hartsuiker et al., 2004) and studies that have found comparable priming effect sizes in the two modalities (Tooley & Bock, 2014) suggest that structural priming operates on a level of representation that is common to production and comprehension (Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Chang, Dell, & Bock, 2006). At present, this issue remains unsettled, but see Tooley and Traxler (2010) for more discussion on this topic.

**Primming Within and Across Languages: Moderating Factors**

*The Lexical Boost Effect*

Although structural priming occurs without the repetition of lexical or conceptual information, in within-language priming studies, larger priming effects have been reported when key lexical items are repeated between the prime and target sentences, usually the head of the target structure. This effect has
been dubbed the **LEXICAL BOOST** (Pickering & Branigan, 1998). The lexical boost effect has been found in production studies (Branigan et al., 2000; Cleland & Pickering, 2003, 2006; Hartsuiker, Berkolet, Schoonbaert, Speybroeck, & Vanderelst, 2008; Pickering & Branigan, 1998; Schoonbaert et al., 2007) as well as in comprehension studies (Arai et al., 2007; Branigan et al., 2005; Ledoux et al., 2007; Scheepers & Crocker, 2004; Tooley et al., 2009; Traxler & Tooley, 2008; Traxler et al., 2014).

In priming research involving comprehension, many studies have found effects with repetition of lexical items but fewer studies have found a priming effect without lexical repetition (Noppeney & Price, 2004; Thothathiri & Snedeker, 2008a; Traxler, 2008a). While this difference has led some researchers to claim that priming in comprehension may rely (at least partially) on different underlying mechanisms than priming in production, studies that have shown priming in comprehension in the absence of lexical repetition indicate that the two processes rely on the same underlying mechanisms to a large extent (Tooley & Traxler, 2010).

The lexical boost effect has also been found in cross-linguistic priming studies when prime and target sentences share translation equivalents of key lexical items, as in within-language priming, typically the head of the target structure. A study conducted by Schoonbaert et al. (2007) tested within-language and cross-linguistic priming among L1 Dutch-L2 English bilinguals and the effects of using translation equivalents of the verbs in each language. The results of this study, which focused on DO/PO dative sentences similar those used in Loebell and Bock (2003), showed equally strong priming effects from L1 Dutch to L2 English and from L2 English to L1 Dutch and a lexical boost in within-language priming for each language as well cross-linguistic priming from L1 Dutch to L2 English. However, while cross-linguistic priming occurred in both directions, the size of the lexical boost effect was smaller when for priming from L2 English to L1 Dutch, compared to the lexical boost effect during priming from L1 Dutch to L2 English.

**Language Proficiency**

Although cross-linguistic priming occurs in both directions, from a bilingual’s L1 to L2 and vice versa, relative proficiency in each language may influence the size of the effect. Loebell and Bock’s (2003) early study of structural priming for active/passive sentences and DO/PO dative sentences between L1 German and L2 English showed bidirectional priming effects during production for the dative
alternation, from German to English and vice versa. While the effect size was the same in both directions, there was a non-significant trend towards greater priming from L1 German to L2 English. Although the subjects who completed this study were highly proficient in both German and English and had been living in an English-speaking environment for between 2–36 years at the time of testing, Loebell and Bock speculated that cross-linguistic priming effects may be stronger when the language of the prime sentences is the bilingual’s stronger language. Providing additional support for this idea, L1 Dutch-L2 English bilinguals who had higher proficiency in L2 English showed a stronger effect of priming for genitive structures from L1 Dutch compared to individuals who had lower proficiency in L2 English (Bernolet et al., 2013).\textsuperscript{27} The difference in the size of the lexical boost effect reported in Schoonbaert et al. (2007) also patterned in this direction—stronger lexical boost effects from L1 to L2 than from L2 to L1.

In this same (2007) study by Schoonbaert and colleagues, the results also showed that when prime and target sentences did not share translation equivalents of the verbs, there was no difference in effect size for within-language priming in L2 English and cross-linguistic priming in both directions, from L1 Dutch to L2 English and vice versa, however, the effect was significantly larger for within-language priming in L1 Dutch. This suggests that compared to structural priming within L1, priming effects may be weaker when they involve a less proficient language. However, other cross-linguistic priming studies have found more similar effect sizes for within-language priming and cross-linguistic priming (Desmet & Declercq, 2006; Kantola & van Gompel, 2011; Weber & Indefrey, 2009), which brings this conclusion into question. While this issue is far from resolved, the general comparability between within-language and cross-linguistic priming effects has been interpreted as evidence that within-language and cross-linguistic structural priming involve the same mechanisms, although differences in proficiency may modulate the priming effect size.

\textsuperscript{27} It’s important to note that the bilinguals in Loebell and Bock’s (2003) study had been living in an English speaking environment for a median of 16 years at the time of testing and more than half could not say whether their stronger language was L1 German or L2 English whereas the bilinguals in Bernolet et al.’s (2013) study had on average 11 years of experience with L2 English and were not living in an English-speaking environment at the time of testing. The fact that differences in priming effect size from L1 German to L2 English and vice versa in Loebell and Bock’s study did not reach significance may be related to the fact that their participants were not clearly dominant in their L1.
**The Inverse Frequency Effect**

Loebell and Bock reasoned in their (2003) finding that repetition of active sentences in L1 German or L2 English did not lead to more frequent production of this structure in the other language, that this was due to the relative high frequency of active structures in both languages. Subsequent research has shown that for higher frequency constructions in a given language, hearing or producing them is less likely to influence their subsequent use compared to hearing or producing lower frequency constructions (Bock & Griffin, 2000; Hartsuiker & Westenberg, 2000; Kaschak, 2007; Kaschak, Kutta, & Jones, 2011). This has been dubbed the **INVERSE FREQUENCY EFFECT** or the **INVERSE PREFERENCE EFFECT** (Pickering & Ferreira, 2008) and is predicted under an error-driven implicit learning account of structural priming in which learning is more sensitive to less frequent information (discussed further in the next section) (Chang, Dell, & Bock, 2006). This also may be tied to proficiency-based differences in structural priming effects in that bilinguals may be exposed to constructions in the less proficient language less frequently, resulting in larger priming effect for these structures from L1 to L2 than vice versa (Schwartz & Kroll, 2006).

**Theoretical Interpretations**

While the presence of structural priming effects is widely taken to reflect the influence of language use on subsequent syntactic processing, there is much debate on how best to characterize this influence. At present, there are two main theoretical accounts of structural priming, which are both supported by a number of empirical findings and are difficult to tease apart.

**Implicit Learning**

The implicit learning account of structural priming holds that producing or comprehending a given syntactic construction strengthens the associated structure building procedures and renders them more accessible during subsequent production or comprehension (Bock & Griffin, 2000). In this connectionist account, the activation of structure building procedures is characterized as a form of error-based learning that is driven by the goal of minimizing prediction error during subsequent syntactic processing (Chang et al., 2006; Chang, Dell, Bock, & Griffin, 2000; Jaeger & Snider, 2013). Crucially, the structure building procedures that are influenced by structural priming are not linked to specific lexical items. In Loebell and
Bock’s (2003) application of this model to account for their findings of cross-linguistic priming for dative structures from L1 German to L2 English and vice versa, the authors posit that syntactic constructions that exist in both of a bilingual’s languages rely on a single set of structure building procedures and use of these procedures in one language makes them more accessible for use in the other language. While Loebell and Bock acknowledge that their findings were compatible with either an implicit learning or residual activation account, more recent work has provided strong evidence of implicit learning in the form of long-term structural priming effects, which last over intervening sentences (Bock et al., 2007; Bock & Griffin, 2000; Hartsuiker & Kolk, 1998; Kaschak, 2007; Kaschak & Borreggine, 2008; Thothathiri & Snedeker, 2008a), between experimental blocks (Kaschak, Kutta, & Jones, 2011), and even days between experimental testing sessions (Kaschak, Kutta, & Schatschneider, 2011). Notably, long-term priming effects have been shown to be equivalent in production and comprehension (Tooley & Bock, 2014). While the error-based implicit learning account of priming can adequately explain structural priming effects that last over intervening sentences and between testing sessions, an account based on the short-term activation of syntactic representations cannot.

Further support for the implicit learning account has come from research showing correlations between structural priming effects and subject performance on an implicit learning task (Kaschak, Kutta, & Jones, 2011) along with the evidence that priming effects can be cumulative, increasing with repeated exposure to prime structures (e.g., Hartsuiker & Westenberg, 2000; Kaschak & Glenberg, 2004; Kaschak, Kutta, & Jones, 2011; Kaschak, Loney, & Borreggine, 2006; Kootstra & Doedens, 2016; but see Hartsuiker, Kolk, and Huiskamp (1999) for an explanation of cumulative priming effects in terms of changes in the resting level of activation for the primed structures). Lastly, the fact that RC attachment preferences (local vs. non-local NP) can also be primed suggests that at least for these sentence types, structural priming does not depend on the residual activation of abstract syntactic representations (as held by the residual activation account, discussed in the next section) since both RC interpretations involve the same structural configurations for the RC lexical items and the availability of RC modification is not thought to be encoded in the lexical entries of nouns (Desmet & Declercq, 2006; see also Ferreira (2003) for a similar argument involving sentential complement structures).
Residual Activation

The residual activation account of structural priming (Pickering & Branigan, 1998) holds that structural priming results from residual activation of syntactic representations associated with the lexical items a recently encountered structure. In this lexicalist account, lexical items are linked to combinatorial nodes that specify the syntactic constructions in which these items can appear (subcategorization frames) and each construction corresponds to a single combinatorial node that is linked to every lexical item that can appear in that construction. Upon hearing or producing an utterance, the lexical items in the utterance are activated along with the combinatorial nodes for the syntactic structures in which they appear. This activation persists for a short period, during which time production or comprehension of a new structure can more readily access the activated combinatorial nodes and lexical items compared to the structural and lexical alternatives. This facilitated access via increased activation leads to facilitated processing for parallel syntactic structures and lexical boost effects, which are attributed to increased facilitation due to activation of the repeated lexical item in addition to the combinatorial node. In Hartsuiker and colleague’s (2004) extension of this model to account for their finding of cross-linguistic structural priming for passive constructions from L1 Spanish to L2 English, they posited that there is a single combinatorial node for constructions that exist in both of a bilingual’s languages and a single conceptual node shared by translation equivalents. Cross-linguistic sharing at both representational levels is able to account for the cross-linguistic priming effect and the cross-linguistic lexical boost following repetition of translation equivalents (e.g., Schoonbaert et al., 2007).

Support for the residual activation account comes from findings of lexical boost effects, since they are dependent on repetition of specific lexical items (or translation equivalents in the case of cross-linguistic priming) and suggest that structural priming is linked to syntactic structures associated with specific lexical items rather than activation of structure building procedures that are not linked to specific lexical items (Ferreira & Bock, 2006). Further support comes from structural priming effects have been elicited following exposure to single words, without exposure to sentences exemplifying the structure being primed. In one study, Salamoura and Williams (2006) were able to bias the production of DO/PO structures in L2 English after exposure to single verbs in L1 Dutch that can only appear in either PO or DO constructions. This effect is difficult to explain in terms of strengthening the procedures associated
with constructing a PO or DO structure and instead point to the activation of syntactic information associated with individual words as the locus of this effect.

One interesting quality of the lexical boost effect is that it has been found to be short lived in comparison to structural priming effects that are not dependent on repetition of lexical material (Branigan et al., 1999; Hartsuiker et al., 2008; Kaschak & Borreggine, 2008). Given the differences in the time course of lexically-independent syntactic priming effects and the lexical boost effects, more recent proposals have suggested that structural priming may entail two mechanisms—a short-lived influence tied to the activation of syntactic information associated with specific lexical items and a longer-lived implicit learning mechanism that operates independently of specific lexical items (Hartsuiker et al., 2008; Tooley & Traxler, 2010; also see Reitter, Keller, and Moore (2011)). While this issue remains a prominent topic of debate, current evidence suggests that both short-term residual activation of syntactic representations and longer-term implicit learning of syntactic processing routines play an important role in structural priming within and across languages.

PRIMING GRAMMATICAL INNOVATIONS

The researched reviewed so far in this chapter has established that for bilinguals, syntactic structures that are shared between their languages (such as the passive in Spanish and English) can be cross-linguistically primed, but it is not known whether use of a structure that is specific to only one of a bilingual’s languages (such as preposition stranding, which occurs in English but not Spanish) exerts a similar degree of influence on syntactic processing in the other language. This question has not been addressed directly, but findings from studies on structural priming of grammatical innovations are informative. The few studies that have examined priming of grammatical innovations have found that limited exposure to a novel or restricted syntactic structure can prime its use in subsequent language production and comprehension.

In line with the present investigation, two studies have examined how exposure to common syntactic structures in English, whose Spanish equivalents are more restricted, affects subsequent production in Spanish. In a study comparing structural priming in Spanish-English bilinguals living in a language contact environment, New York City, and in a non-contact environment, Argentina, Carando (2015) showed that both groups produced higher rates of Spanish sentences with dispreferred verbal
argument structures in Spanish following exposure to parallel structures both in English and in Spanish. Exposure to a passive sentence in either language resulted in a greater likelihood that an unrelated picture would be described with a passive in Spanish. Likewise, exposure to a transitive sentence describing a reciprocal action in either language (The chef hugs the policeman. / La cocinera abraza al policía.) led to increased production of the same structure in a picture description task and exposure to a double object dative structure in either language (The janitor gave the nurse a present. / El portero le dio a la enfermera un regalo.) resulted in more frequent production of this structure in Spanish.

In the same results, Carando also found that following prime sentences in both languages, both bilingual groups produced Spanish sentences with novel structures mirroring English, albeit at very low rates (2.9% for the contact group and 0.9% for the non-contact group). Both groups produced Spanish conjoined NP reciprocal sentences without the obligatory reflexive marker se (La cocinera y el policía Ø abrazan. “The chef and the policeman hug.”) and double object dative sentences without the obligatory dative clitic le (El portero Ø dio a la enfermera un regalo. “The janitor gave the nurse a present.”), while only the contact group produced active sentences without the obligatory accusative marker a (La bailarina empuja Ø el portero. “The dancer pushes the janitor.”). Importantly, these novel structures were produced more often following parallel English sentences (versus following Spanish sentences) and the contact group produced over three times the number of English-like structures as did the non-contact group.

Taken together, Carando’s findings suggest that commonly occurring L2 structures can prime the production of novel or restricted L1 structures and that differences in exposure to L2 and language dominance (L1 vs. L2) can subtly influence cross-linguistic priming rates. Crucially, Carando points out that neither group produced double object dative sentences omitting both the obligatory dative clitic le and dative marker a (El portero Ø dio Ø la enfermera un regalo. “The janitor gave the nurse a present.”) contrary to expectations. Carando suggests that this absence reveals a constraint of cross-linguistic

28 The preferred reciprocal form in Spanish contains a conjoined noun phrase subject and reciprocal verb form, e.g., La cocinera y el policía se abrazan. “The chef and the policeman hug.”
29 The Spanish double object dative structures tested in Carando’s study were generated by scrambling and licensed by the presence of the dative le clitic and dative a marker (El portero le dio a la enfermera un regalo. “The janitor gave the nurse a present”). Without these function morphemes, the double object dative construction is illicit in Spanish (Flett, Branigan, & Pickering, 2013).
structural priming—exposure to a structure in one language is not sufficient to prime its production in the other; the structure must also have a model elsewhere in the target language.30

Hsin et al.’s (2013) study of cross-linguistic structural priming among bilingual children also produced similar results. The results of this study, in which Spanish-English bilingual children (ages 4–5) were asked to describe an object in Spanish following the researcher’s description of a similar object in English, showed that after hearing English descriptions consisting of an adjective-noun sequence (e.g., an open book), children produced significantly more structurally illicit descriptions in Spanish exhibiting the same word order (e.g., un abierto libro) rather than the typical noun-adjective Spanish order (e.g., un libro abierto). The authors interpreted these findings as evidence that illicit core syntactic structures can be primed between a bilingual’s languages. However, it is important to note that while Spanish adjectives typically follow the nouns that they modify, in certain contexts, the adjective must precede the noun (e.g., un gran amigo means a great friend while un amigo grande means a big friend). Thus, while these findings suggest that novel core syntactic structures can be cross-linguistically primed, they do not provide evidence as to whether this is possible for L1 structures that do not exist anywhere in the target language.

Perhaps most informative for the present study, two studies conducted with English monolinguals have shown that syntactic processing of entirely novel syntactic structures can be facilitated following repeated exposure to them. In their innovative study, Kaschak and Glenberg (2004) showed that the comprehension of sentences featuring a structure from an unfamiliar dialect of English, the needs construction (e.g., The meal needs cooked given that dinner is in an hour. cf. The meal needs to be cooked given that dinner is in an hour.) was facilitated following fairly limited exposure to sentences containing this structure during the experimental session. A follow-up experiment further demonstrated that subjects generalized learning of the needs construction during processing of similarly novel sentences containing the verb wants (e.g., The valiant hero wants recognized for his courageous actions.

30 Thus, Spanish active transitive sentences without accusative a could be primed because this marker is not required with inanimate accusative objects. Similarly, priming reciprocal constructions without reflexive se was possible because other reciprocal verbs in Spanish do not require the se marker. On the other hand, there are no contexts in which Spanish double object dative sentences can omit both the dative clitic le and dative marker a, which explains why the English double object dative construction did not prime a parallel sentence in Spanish.
In a replication of Kaschak and Glenberg (2004), Fraundorf and Jaeger (2016) found similar results and further showed that adaptation to the novel structures was not strategic but rather was due to implicit learning via cumulative structural priming. While these studies do not bear directly on questions related to cross-linguistic structural priming, these findings are an important indication that even limited exposure to a novel syntactic structure can lead to rapid changes in native language syntactic processing. While this influence has been shown for monolingual syntactic processing, similar influence from exposure to commonly-occurring structures in a second language on syntactic processing structurally-parallel novel structures in the first language has not been tested.

CONCLUSION

Although the research on bilingual syntactic processing reviewed above is still very recent, it has already produced important findings that have illuminated the ways in which both short and long term changes in language exposure and use can impact how bilinguals access and implement syntactic knowledge to process language in real time. One clear finding in this research is that both languages are active and interacting during bilingual syntactic processing. Even when only using one language, the evidence from lexical integration research suggests that bilinguals activate both languages. Furthermore, evidence from language switching studies suggest that syntactic information from both languages must be activated at the same time for fluid code-switching to take place (Moreno et al., 2002). The evidence from cross-linguistic structural priming studies has shown a significant degree of integration in the procedures and representations involved bilingual syntactic processing, and several factors related to the repetition of lexical items, the frequency of the structure in question, and individuals’ relative proficiency in each language have been found to influence the strength and direction of cross-linguistic influence.

While the heritage language research reviewed in the previous chapter has suggested that heritage language core syntax is largely impervious to cross-linguistic influence, evidence from the psycholinguistic studies presented in this chapter suggest that the picture is likely more complex. The

31 An important topic that has not been discussed here is that of CONVERGENCE—the development of bilingual grammatical representations and processing procedures that are qualitatively different from those found in either L1 or L2. For a summary of research in this area, see Schwartz and Kroll (2006).
bilingual syntactic processing research reviewed in this chapter indicates that, in the words of Desmet and Duyck (2007) “…it is not possible during speaking or listening for people to ‘switch off’ their native language or even their second language and process language in a purely monolingual mode” (p. 169). One possible reason for the mismatch between the conclusions drawn in the heritage speaker and bilingual processing research may lie in the different methodological approaches. The methods used in the heritage language research to date—almost exclusively offline methods—are not designed to capture subtle influences of the dominant language on heritage language syntactic processing like those found in the bilingual syntactic processing literature. In the case of heritage speakers, who are dominant in their L2, it would not be surprising to find at least the same degree of cross-linguistic influence on syntactic processing that has been found for late bilinguals, both in terms of the dominant language biasing competition between alternative structures within the heritage language and reinforcing structures that are shared with the heritage language.

In bilingual syntactic processing research, the evidence has come from two experimental paradigms: For structures that are similar in L1 and L2, such as the passive in Spanish and English, cross-linguistic structural priming has been used to probe the extent to which they share abstract syntactic representations and structure building procedures; for aspects of syntactic processing that conflict in L1 and L2, such as RC attachment preferences in Spanish and English, online processing measures have been used to show how processing syntactic ambiguities for one language changes following exposure to the other language. Of these two paradigms, only cross-linguistic priming allows the researcher to manipulate the activation of one language in real time and measure the direct effects on syntactic processing in the other. While cross-linguistic structural priming has been used extensively to show how syntactic processing in one language reinforces syntactic processing in the other language for shared structures, this paradigm is also ideal for testing how syntactic processing in one language can interfere, or compete with syntactic processing procedures in the other.

Concerning bilingual competition and reinforcement among heritage speakers, one potentially important question that has not been addressed is whether repeated syntactic processing of a structure that a priori exists only in the dominant language can increase the availability of the associated syntactic representations and/or structure building procedures for use in the heritage language. That is, beyond
influencing the processing preferences between two options that are permitted in the heritage language (e.g., high and low RC attachment are both permitted in Spanish and English), this question asks whether sustained exposure to and use of the dominant language can result in a situation in which a syntactic structure that was formerly exclusive to the dominant language now competes with heritage language structures during syntactic processing in the heritage language.

The ambiguous RC constructions that Dussias (2004) and Dussias and Sagarra (2007) investigated are fairly common in both Spanish and English and RC attachment preferences reflect statistical tendencies, not categorical rules. A stronger test of the limits of cross-linguistic influence on syntactic processing is to test whether syntactic structures that are specific to one language can become viable options during syntactic processing of the other language. The present study aims to do this by testing syntactic processing of a core syntactic property (preposition stranding) and whether exposure to this common property in English makes the corresponding structure and syntactic processing routines available for Spanish. The next chapter introduces the methods used in the current study to address this question.
CHAPTER 4: METHODS

OVERVIEW OF EXPERIMENTS

The primary objective of the present study was to determine whether and to what extent heritage language syntactic processing of core syntax is influenced by heritage speakers’ dominant language. To this end, the main experiment in the present study tested whether exposure to English sentences that feature preposition stranding—a core syntactic property of English that is not attested for any variety of Spanish—can facilitate syntactic processing of structurally-parallel but ungrammatical Spanish sentences in a cross-linguistic structural priming paradigm. Preposition stranding refers to a syntactic operation in which a prepositional object has been moved, for example during formation of a wh-question or relative clause, while the preposition that selects for the prepositional object remains in its base position (Law, 2006). Preposition stranding, while a commonly occurring feature of English wh-questions and relative clause sentences, does not occur in Spanish (Law, 2006; Zagona, 2002). In the priming experiment, adult heritage Spanish speaker subjects listened to grammatical English sentences featuring preposition stranding like (8a) followed immediately by ungrammatical structurally-parallel Spanish sentences like (8b) (ungrammaticality indicated with “*”) while response time (RT) data were recorded.

8. a. These are the scissors that David cut the paper with.
   b. *Este es el serrucho que Eduardo cortó la rama con para hacer leña.
      “This is the saw that Eduardo cut the branch with to make firewood.”

The secondary objective of the present study was to determine how cross-linguistic influence on heritage language syntactic processing is affected by extralinguistic variables related to exposure, use, and proficiency for the dominant and heritage language. This objective was addressed by including specific quantitative measures of language exposure, use, and proficiency in mixed-effects modeling of the RT data collected during the cross-linguistic structural priming experiment. Data pertaining to language exposure, use, and proficiency were collected via a language background questionnaire (the Bilingual Language Profile (BLP)) and an oral fluency task administered during a second visit to the lab. During this second visit to the lab, subjects also completed an acceptability judgment experiment that...
probed their intuitions about preposition stranding in Spanish sentences like (8b). The purpose of the acceptability judgment experiment was to investigate how subjects perceived the grammaticality of the target sentences when these sentences were encountered in isolation. To determine whether the results of these experimental measures are unique to heritage Spanish speakers or if they are reflected more broadly among other Spanish-English bilinguals, a control group of late Spanish-English bilinguals also completed the same tasks following the same procedures.

During the first testing session, subjects first completed the cross-linguistic structural priming experiment and then the BLP. During the second session, which occurred at least two weeks later, subjects first completed the acceptability judgment task, and then the oral fluency task in both languages. Subjects received $30 payment at the end of each session. This study was approved by the City University of New York Institutional Review Board (IRB).

RESEARCH QUESTIONS AND HYPOTHESES

The research questions and hypotheses of the present study are outlined below.

**RQ 1:** For heritage Spanish speakers, does exposure to preposition stranding in English sentences, as in (8a), facilitate syntactic processing of (i.e., prime) structurally parallel but ungrammatical Spanish sentences, as in (8b)?

**Hypothesis 1:** The hypothesis for RQ 1 is that syntactic processing of ungrammatical Spanish sentences exhibiting preposition stranding will be facilitated for heritage Spanish speakers following exposure to preposition stranding in their dominant language, English. Facilitated processing will be indicated by faster RTs at critical points in the ungrammatical Spanish sentences (Mitchell, 2004). This hypothesis is supported by findings in the research outlined in Chapter 2. First, the patterns of results obtained for offline tasks in heritage language experimental research suggest that heritage speakers’ performance on these tasks may be affected by dominant language influence during heritage language syntactic processing. Most relevant to the present study, Pascual y Cabo and Soler (2015) showed that adult heritage Spanish speakers were somewhat accepting of Spanish sentences that featured preposition stranding although they produced these structures to a lesser extent during a subsequent oral production task. This pattern of results suggests that the increased acceptance of preposition stranding may be due to influence from English during syntactic processing for these sentences, rather than stable
changes in heritage speakers’ representational knowledge of Spanish. Second, the research on bilingual processing summarized in Chapter 3 has shown a high degree of integration between a bilingual’s languages at multiple levels of representation and suggests that even while bilinguals are performing tasks exclusively in one language they are not able to completely inhibit their other language. While cross-linguistic influence on syntactic processing has only been shown for syntactic structures that are common to both of a bilingual’s languages (e.g., the passive structure in Spanish and English), the limited research that has examined structural priming of grammatical innovations suggests that exposure to a novel structure (i.e. a structure that is a priori not licensed by the grammatical constraints of the target language) can have an immediate effect of facilitating syntactic processing for subsequently encountered sentences that exhibit the same novel structure.

**RQ 2:** If exposure to preposition stranding in English facilitates syntactic processing of Spanish preposition stranding during the cross-linguistic structural priming experiment, is the degree of facilitation (the priming effect size) modulated by individual differences related to exposure, proficiency, and current use for the heritage and dominant language?

**Hypothesis 2:** At present, there is no theory that provides a principled account for how extralinguistic factors (e.g., amount of exposure to a later-learned language) modulate cross-linguistic influence during L1 processing (Kroll & Dussias, 2013). However, the empirical findings outlined in Chapter 2 and Chapter 3 suggest that the magnitude of influence from the dominant language during heritage language syntactic processing is likely to be affected by aspects of language proficiency, exposure, and use. The available research on heritage language syntactic processing is limited, but several studies have suggested that age of exposure to the dominant language is likely to play an important role (Bolger & Zapata, 2011). Following these suggestions and the research on cross-linguistic lexical activation and syntactic processing that has shown stronger cross-linguistic priming effects from bilinguals’ dominant language to their non-dominant language (e.g., Kootstra & Doedens, 2016 and references therein), the hypothesis for RQ 2 is that the cross-linguistic structural priming effects obtained for the main experiment in the present study will be largest for heritage speakers who are more dominant in English—those who acquired English from birth or during early childhood, have spent most of their lives in a predominantly English-speaking environment, currently use more English than Spanish on a
daily basis, and show relatively higher proficiency in English compared to Spanish. For the late bilingual control subjects, who are Spanish dominant, have spent more of their lives in a Spanish-speaking environment, and have had the least amount of exposure to English, the priming effect is expected to be extremely reduced or absent although the priming effect may be present for control subjects who have had more exposure to English and currently use more English than Spanish. These predictions are also supported by findings from a recent ERP study that showed that amount of cumulative exposure to English and current levels of Spanish usage modulated syntactic processing responses to English-like structural violations in Spanish for both heritage Spanish speakers and late Spanish-English bilinguals (Martohardjono, Phillips, Madsen II, & Schwartz, 2017).

CROSS-LINGUISTIC STRUCTURAL PRIMING EXPERIMENT

Subjects

A total of 63 Spanish-English bilinguals participated in the present study, including 41 adult heritage Spanish speakers (HS) and 22 adult late Spanish-English bilinguals (LB). All subjects resided in the greater New York City area at the time of testing and were recruited via email and flyers posted around college campuses at the City University of New York. To determine eligibility for this study, all subjects completed a language background screener, which included questions pertaining to language exposure and use during childhood and adolescence along with biographical items such as age, education, and caregivers’ countries of origin. (See Appendix A for screener items.) All subjects who participated in the present study also completed the BLP—a short questionnaire designed to measure language dominance for bilinguals through a set of questions pertaining to a subject’s language history, current use, self-rated proficiency, and attitudes for both Spanish and English (Gertken, Amengual, & Birdsong, 2014). Group summaries for biographical data along with measures of language exposure, use, and proficiency collected via the BLP are shown below in Table 1. A discussion of the BLP questionnaire

32 While there is evidence that larger structural priming effects are elicited for uncommon structures, it is not clear whether this pattern also holds for structures that a priori do not exist in the target language.
items in Table 1 is given in the below section, *Bilingual Language Profile*, and the oral fluency measure is described below in *Oral Fluency Task*.

Table 1: Subject characteristics by group for heritage Spanish speakers and late Spanish-English bilinguals.

<table>
<thead>
<tr>
<th>Subject Characteristics33</th>
<th>HS N = 41 (31 female)</th>
<th>LB N = 22 (11 female)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age at time of testing (years)</strong></td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>24.51 (4.99)</td>
<td>18–39</td>
<td>30.45 (8.63)</td>
</tr>
<tr>
<td><strong>Education level</strong></td>
<td>2.73 (1.12)</td>
<td>1–6</td>
</tr>
<tr>
<td><strong>Language dominance</strong></td>
<td>47.49 (31.15)</td>
<td>-24.97–129.95</td>
</tr>
<tr>
<td><strong>Exposure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>English age of acquisition (years of age) (AGE-E)</strong></td>
<td>4.07 (2.35)</td>
<td>0–8</td>
</tr>
<tr>
<td><strong>Age of arrival to U.S. (years) (AOA-US)</strong></td>
<td>1.7 (2.55)</td>
<td>0–8</td>
</tr>
<tr>
<td><strong>Length of residence in U.S. (years) (LOR-US)</strong></td>
<td>22.82 (6.06)</td>
<td>13–39</td>
</tr>
<tr>
<td><strong>Use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Proportion of daily interactions in Spanish (USE-S)</strong></td>
<td>0.31 (0.14)</td>
<td>0.07–0.67</td>
</tr>
<tr>
<td><strong>Proficiency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Self-rated Spanish speaking &amp; understanding (PSU-S)</strong></td>
<td>4.98 (1.04)</td>
<td>1.5–6.0</td>
</tr>
<tr>
<td><strong>Self-rated Spanish reading &amp; writing</strong></td>
<td>4.23 (1.4)</td>
<td>1.0–6.0</td>
</tr>
</tbody>
</table>

33 Calculations for Age of arrival to U.S. include only HS who were born outside of the U.S. (n = 16). For Education level, 1 = high school diploma, 2 = some college, 3 = 4-year college degree (B.A./B.S.), 4 = some graduate school, 5 = Master’s degree, 6 = terminal degree (PhD/MD/JD). Oral fluency is reported for 21 LB and 29 HS. Abbreviations for predictor variables that were entered in the analysis of the baseline syntactic processing, structural priming, and acceptability judgment results are indicated in small caps.
### Heritage Spanish Speakers

The heritage Spanish speakers who were enrolled in the present study were 18–39 years old at the time of testing ($M = 24.51$, $SD = 4.99$) and were either born in the U.S. ($n = 25$) or were born in a Spanish-speaking Latin American country$^{34}$ and brought to the U.S. by age 8 ($AOA-US$) ($M = 1.7$, $SD = 2.55$). All subjects were raised speaking Spanish by caregivers who themselves were born and raised in Spanish-speaking Latin America and immigrated to the U.S. after age 18. Subjects were born within 20 years of their caregivers’ arrival to the U.S. and at the time of testing, subjects in this group had been living in the U.S. for 13–39 years ($LOR-US$) ($M = 22.82$, $SD = 6.06$). These subjects’ formal education levels ranged from high school diploma to terminal degree (PhD/MD/JD).

### Late Learners of English

The late Spanish-English bilinguals tested in this study were raised from birth speaking Spanish in a Spanish-speaking Latin American country$^{36}$ and became immersed in English in adulthood. Late bilinguals who were enrolled in this study were 19–46 years old at the time of testing ($M = 30.45$, $SD = 8.63$) and arrived in the U.S. between ages 15–34 ($AOA-US$) ($M = 23.18$, $SD = 6.15$). At the time of testing, these subjects had been living in the U.S. between 0.5–31 years ($LOR-US$) ($M = 7.27$, $SD = 8.33$). These subjects’ formal education levels also ranged from high school diploma to terminal degree (PhD/MD/JD).

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$^{34}$ Heritage Spanish speakers were born in the following countries: U.S. ($n = 25$), Mexico ($n = 6$), Colombia ($n = 4$), Dominican Republic ($n = 2$), Argentina ($n = 1$), Honduras ($n = 1$), Puerto Rico ($n = 1$), Venezuela ($n = 1$).

$^{35}$ For subjects who were born in the U.S., a value of 0 was used for the $AOA-US$ calculation that includes all 41 heritage speaker subjects. Those 16 heritage speaker subjects who were born outside of the U.S. arrived between 0.5–8 years of age ($M = 4.34$, $SD = 2.24$).

$^{36}$ Late learners of English were born and raised in the following countries: Colombia ($n = 4$), Dominican Republic ($n = 4$), Mexico ($n = 3$), Uruguay ($n = 3$), Ecuador ($n = 2$), Peru ($n = 2$), Argentina ($n = 1$), Chile ($n = 1$), El Salvador ($n = 1$), Venezuela ($n = 1$).
Materials

*Experimental Stimuli*

Spanish allows subject, object, indirect object, and oblique object relative clauses (Zagona, 2002). In Spanish, if a prepositional object is moved in the derivation of a *wh*-question or RC, the preposition must appear preceding the *wh*-element or relative pronoun, as in (10c) (cf. (10b)). Spanish, unlike English, does not allow the preposition to remain in its base position when the prepositional object is relativized (cf. (9b) and (10b)).

9. a. *Edward cut the branch with the saw.*
   
   b. *This is the saw [that Edward cut the branch with __].*

10. a. *Eduardo corto la rama con el serrucho.*

   “Eduardo cut the branch with the saw.”

   b. *Este es el serrucho [que Eduardo cortó la rama con __].*

   “This is the saw that Eduardo cut the branch with.”

   c. *Este es el serrucho [con que Eduardo cortó la rama __].*

   “This is the saw with which Eduardo cut the branch.”

Two types of Spanish declarative sentences exhibiting preposition stranding within an RC were tested in the cross-linguistic structural priming experiment. The first type, exemplified in (8b) (repeated below as (11a)), contained a relativized instrumental prepositional object (*el serrucho* ‘the saw’) and a stranded preposition *con* “with” in its base position within the RC. The second type, exemplified in (11b), contained a relativized locative prepositional object (*la tienda* “the store”) and a stranded preposition *en* ‘in” in its base position within the RC.

11. a. *Este es el serrucho que Eduardo cortó la rama con para hacer leña.*

   “This is the saw that Eduardo cut the branch with to make firewood.”

   b. *Esta es la tienda que Gonzalo compró el pollo en para cocinar la cena.*

   “This is the store that Gonzalo bought the chicken in to cook dinner.”
All of the Spanish preposition-stranded (PS) sentences exemplified in (11a–b) were structurally identical through the stranded preposition, contained the same relative pronoun (que "that"), and differed only in the thematic role of the relativized prepositional object and the corresponding preposition. An adjunct phrase modifying the RC VP was added to the end of Spanish PS sentences to avoid overlap between processing of the stranded preposition and sentence wrap-up effects. These sentence final phrases were 2–5 words long and varied in structure between target items. While the sentence structure exemplified in (11a–b) is grammatical and very common in English, it is ungrammatical in Spanish. In Spanish, the preposition must appear preceding the relative pronoun at the beginning of the relative clause modifying the prepositional object (cf. Este es el serrucho con que Eduardo cortó la rama para hacer leña. “This is the saw with which Eduardo cut the branch to make firewood.” and Esta es la tienda en que Gonzalo compró el pollo para cocinar la cena. “This is the store in which Gonzalo bought the chicken to cook dinner.”). A total of 24 con sentences and 22 en sentences were constructed with 43 unique RC verbs and common vocabulary items. Familiarity with the vocabulary items was verified by two bilinguals who did not participate in this study: one heritage Spanish speaker and one Spanish-dominant late bilingual.

For each of the en and con target sentences, two corresponding English sentences were constructed with translation equivalents of the RC verb and preposition. The English PS prime sentences, exemplified in (12a–b), featured the same structure as the Spanish PS target sentences through the stranded preposition while the English control sentences, exemplified in (13a–b), featured a different structure in which the direct object was relativized, rather than the prepositional object. All prime and control sentences featured the same relative pronoun (that). The full list of con and en target

37 Three verbs, escribió “wrote”, vio “saw”, and hizo “made” appeared once in both the en and con target sentences.
38 The prime and target sentences in this experiment shared translation equivalents of the relative clause verbs and prepositions in order to increase the likelihood of eliciting a priming effect. As noted in Chapter 3, priming effects have been elicited in production studies with and without repetition of lexical material between the prime and target items, although the magnitude of the priming effects is often larger when the head of the structure being primed is repeated between prime and target sentences (Pickering & Branigan, 1998). In contrast, fewer studies have found priming effects during comprehension without repetition of lexical material between primes and targets (Traxler et al., 2014).
sentences can be found in Appendix B and Appendix C, respectively, along with the English prime and control sentences for each target.

12. a. These are the scissors that Mary cut the paper with.
   
b. This is the flower shop that David bought the plant in.

13. a. This is the paper that Mary cut with the scissors.
   
b. This is the plant that David bought in the flower shop.

The prepositions en “in” and con “with” were selected based on two factors: the diversity of transitive verbs that they can modify and the frequency with which their English translation equivalents occur as stranded prepositions. As a rough measure of frequency of stranding for English prepositions, I identified the prepositions in English that occur most frequently in sentence-final position across declarative and interrogative sentences using the Corpus of Contemporary American English (Davies, 2008). The top five most frequent sentence-final prepositions and their relative frequencies per million words are shown below in Table 2.

Table 2: The five most frequent sentence-final prepositions in English. Frequency per million words is shown by sentence type (interrogative vs. declarative) along with average frequency and total frequency across sentence types.

<table>
<thead>
<tr>
<th>Interrogative sentences</th>
<th>Frequency per million words</th>
<th>Declarative sentences</th>
<th>Frequency per million words</th>
<th>Average frequency across sentence types</th>
<th>Total frequency across sentence types</th>
</tr>
</thead>
<tbody>
<tr>
<td>for</td>
<td>10752</td>
<td>for</td>
<td>17283</td>
<td>14018</td>
<td>28035</td>
</tr>
<tr>
<td>to</td>
<td>5557</td>
<td>to</td>
<td>16908</td>
<td>11233</td>
<td>22465</td>
</tr>
<tr>
<td>with</td>
<td>4846</td>
<td>with</td>
<td>17553</td>
<td>11200</td>
<td>22399</td>
</tr>
<tr>
<td>about</td>
<td>6999</td>
<td>about</td>
<td>13981</td>
<td>10490</td>
<td>20980</td>
</tr>
<tr>
<td>in</td>
<td>11208</td>
<td>in</td>
<td>3274</td>
<td>7241</td>
<td>14482</td>
</tr>
</tbody>
</table>

In declarative sentences, with is the preposition that occurs most frequently in sentence-final position, with 17,553 occurrences per million words, and in is the ninth most frequent preposition in this
position, with 3,274 occurrences per million words (Davies, 2008). In interrogative sentences, *in* occurs most frequently in sentence-final position, with 11,208 occurrences per million words, and *with* is the sixth most frequent sentence-final preposition in these sentences, with 4,846 occurrences per million words (Davies, 2008). The fact that *with* and *in* each have only one translation in Spanish increases the likelihood that hearing these English prepositions in the prime sentences will activate the expected translation equivalents, *con* and *en* in the Spanish target sentences. Additionally, the prepositions *with/con* and *in/en* are able to head prepositional phrases that can modify a variety of transitive verbs, which allows for the creation of sufficient stimulus sentences for each preposition.

Additional stimulus characteristics for the Spanish target and English prime and control sentences are shown below in Table 3. Spanish target sentences were 12–15 words long (*M* = 13.78, *SD* = 0.84) and English prime and control sentences were 10–11 words long (*M* = 10.04, *SD* = 0.21). (Spanish target sentences were longer due to the sentence-final VP-modifying phrase.) In all sentences, the critical sentence segment (segment 3) contained four words: the RC verb, the direct object (in targets and primes) or prepositional object (in controls), and the preposition. In the Spanish target sentences, the sentence-final segment (segment 4) consisted of the RC VP-modifying phrase. Further description of stimulus segmentation is given in the next section, Segmentation.

The RC verbs for Spanish target sentences were 2–4 syllables long (*M* = 2.85, *SD* = 0.73) and always appeared in the past tense. Frequency for Spanish RC verbs was determined using the SUBTLEX-ESP Spanish word frequency list based on a corpus of 41 million words taken from subtitles of films and television shows that aired between 1990–2009 (Cuetos, Glez-Nosti, Barbón, & Brysbaert, 2009). The prepositions *for, to,* and *about* also frequently appear in sentence-final position in English, however these prepositions were not selected due to potential issues that their translation equivalents in Spanish might introduce into the experiment. In Spanish, *for* has two translations, *por* and *para,* which differ in meaning and usage following predictable patterns. While English sentences could be created in such a way that the preposition *for* unambiguously translates into either *por* or *para,* the restricted usage of each term in Spanish would make it difficult to create the necessary number of target sentences with unique verbs that can be modified by a prepositional phrase with either *por* or *para.* The preposition *to* translates to *a* in Spanish, and was not used because of the possibility that the *a* in Spanish target sentences would not be parsed as *to* but rather might be perceived to be part of the offset of the preceding word or part of the onset of the following word. The preposition *about* and its translation equivalent *sobre* meet the requirements of the experimental design but were not used to limit the length of the experiment.
This list was used to obtain word frequency data as the spoken language in film and television subtitles is likely similar to the Spanish input that the subjects in the present study would have received. Spanish target RC verbs occurred between 0.19–471.35 times per million words ($M = 46.17$, $SD = 101.54$) and 6 out of the 43 unique RC verbs (13.95%) were English cognates. In the English prime/control sentences, the RC verb was 1–4 syllables long ($M = 1.33$, $SD = 0.63$) and always appeared in the past tense. Frequency for English RC verbs was determined using the *SUBTLEX-US* English word frequency list based on a corpus of 51 million words taken from subtitles of U.S. films and television shows that aired between 1900–2007 (Brysbaert & New, 2009). English RC verbs occurred between 2.59–2341.37 times per million words ($M = 171.05$, $SD = 368.88$). The percent of cognates for English RC verbs is the same (13.95%) since verb translation equivalents were used between English prime/control and Spanish target sentences.

The prepositional object NPs for Spanish target sentences were 1–5 syllables long ($M = 2.57$, $SD = 0.83$), their frequency ranged from 0.41–278.63 per million words ($M = 41.45$, $SD = 53.57$) based on the *SUBTLEX-ESP* frequency list, none of the prepositional object NPs were animate, 100% were concrete, and 21 had English cognates (45.65%). The prepositional object NPs for English control/prime sentences were 1–4 syllables long ($M = 1.67$, $SD = 0.79$), their frequency ranged from 0.37–439.51 per million words ($M = 53.19$, $SD = 87.03$) based on the *SUBTLEX-US* frequency list, none were animate, 100% were concrete, and 9 had Spanish cognates (19.56%).

Finally, the direct object NPs for Spanish target sentences were 2–5 syllables long ($M = 2.61$, $SD = 0.8$), their frequency ranged from 2.64–1047.36 per million words ($M = 77.35$, $SD = 160.47$), 10 out of 46 (21.74%) direct object NPs were animate, 42 were concrete (91.3%), and 14 had English cognates (30.43%). The direct object NPs for English control/prime sentences were 1–3 syllables long ($M = 1.61$, $SD = 0.71$), their frequency ranged from 3.16–5247.45 per million words ($M = 174.69$, $SD = 768.89$), 7 out of 46 (15.22%) were animate, 40 were concrete (86.96%), and 14 had Spanish cognates (30.43%).
Table 3: *Stimulus characteristics for Spanish target sentences and English prime and control sentences.*

<table>
<thead>
<tr>
<th>Stimulus Characteristics</th>
<th>Spanish Target Sentences</th>
<th>English Prime / Control Sentences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentence length</td>
<td>12–15 (M = 13.78, SD = 0.84)</td>
<td>10–11 (M = 10.04, SD = 0.21)</td>
</tr>
<tr>
<td>Segment 3 length</td>
<td>4–4 (M = 4, SD = 0)</td>
<td>4–4 (M = 4, SD = 0)</td>
</tr>
<tr>
<td>Segment 4 length</td>
<td>2–5 (M = 3.78, SD = 0.84)</td>
<td>NA</td>
</tr>
<tr>
<td>RC verb length</td>
<td>2–4 (M = 2.85, SD = 0.73)</td>
<td>1–4 (M = 1.33, SD = 0.63)</td>
</tr>
<tr>
<td>RC verb frequency</td>
<td>0.19–471.35 (M = 46.17, SD = 101.54)</td>
<td>2.59–2341.37 (M = 171.05, SD = 368.88)</td>
</tr>
<tr>
<td>RC verb cognate status</td>
<td>6/43 (13.95%)</td>
<td>6/43 (13.95%)</td>
</tr>
<tr>
<td>Prepositional object NP length</td>
<td>1–5 (M = 2.57, SD = 0.83)</td>
<td>1–4 (M = 1.67, SD = 0.79)</td>
</tr>
<tr>
<td>Prepositional object frequency</td>
<td>0.41–278.63 (M = 41.45, SD = 53.57)</td>
<td>0.37–439.51 (M = 53.19, SD = 87.03)</td>
</tr>
<tr>
<td>Prepositional object NP animacy</td>
<td>0/46 (0%)</td>
<td>0/46 (0%)</td>
</tr>
<tr>
<td>Prepositional object concreteness (%)</td>
<td>46/46 (100%)</td>
<td>46/46 (100%)</td>
</tr>
<tr>
<td>Prepositional object cognate status (%)</td>
<td>21/46 (45.65%)</td>
<td>9/46 (19.56%)</td>
</tr>
<tr>
<td>Direct object NP length</td>
<td>2–5 (M = 2.61, SD = 0.8)</td>
<td>1–3 (M = 1.61, SD = 0.71)</td>
</tr>
<tr>
<td>Direct object frequency</td>
<td>2.64–1047.36 (M = 77.35, SD = 160.47)</td>
<td>3.16–5247.45 (M = 174.69, SD = 768.89)</td>
</tr>
<tr>
<td>Direct object NP animacy</td>
<td>10/46 (21.74%)</td>
<td>7/46 (15.22%)</td>
</tr>
<tr>
<td>Direct object concreteness (%)</td>
<td>42/46 (91.3%)</td>
<td>40/46 (86.96%)</td>
</tr>
<tr>
<td>Direct object cognate status (%)</td>
<td>14/46 (30.43%)</td>
<td>14/46 (30.43%)</td>
</tr>
</tbody>
</table>

The sentences described above were grouped into two-sentence trials for presentation in the priming experiment. In prime trials, a Spanish target sentence, like (11a) or (11b), was preceded by the corresponding English prime sentence, like (12a) or (12b), containing the same structure and translation equivalents of the verb and preposition. In control trials, a Spanish target sentence was preceded by the
corresponding English control sentence, like (13a) or (13b), which shared the same lexical items as the corresponding prime but differed in structure. Prime and control trials were counterbalanced over two versions of the experiment to permit comparisons between identical Spanish targets. In version 1, half of the en and con target sentences were presented in prime trials and the other half were presented in control trials. In version 2, the trials were flipped so that the target sentences that appeared in prime trials in version 1, appeared in control trials in version 2, and vice versa.

In addition to the prime, control, and target sentences, a set of 10 grammatical Spanish object RC sentences were included in each experiment version to obtain a baseline syntactic processing profile for heritage speakers and late bilinguals. Six of the sentences contained a relativized direct object and the relative pronoun que “that” introducing the relative clause, as in (14a), and four of the sentences contained a relativized oblique object and the relative pronoun donde “where” introducing the relative clause, as in (14b).

14. a. *Estas son las camisas que Sofia regaló a la iglesia el año pasado.*
   “These are the shirts that Sofia donated to the church last year.”

   b. *Este es el cuarto donde Sara puso su oficina cuando se mudó.*
   “This is the room where Sara put her office when she moved.”

In both experiment versions, the two-sentence priming trials and Spanish RC sentences were interspersed with the same filler sentences, described below, and were pseudorandomized so that the same trial type never appeared in succession and at least two fillers appeared between trials. Participants completed only one version of the experiment and heard each stimulus sentence only once. Approximately equal numbers of subjects in each group completed versions 1 and 2. Sentences were digitally recorded as natural running speech with neutral prosody by a male Spanish-dominant late bilingual who was raised in the Dominican Republic and U.S. (arrived to the U.S. at age 14) using Audacity recording and editing software, sampled at 44.1 kHz. After recording, sentences were leveled to an average loudness (RMS value) of -26 dB in Audacity and then segmented following the procedures outlined in the next section.
**Segmentation**

All experimental and filler sentences were split into 3–5 segments for presentation in the self-paced listening paradigm. Spanish PS target sentences were uniformly split into four segments at these points: following the prepositional object NP, the subject NP, and the stranded preposition. In these sentences, segment 3 is the critical region that contains the RC verb, direct object, and stranded preposition and is where the filler-gap dependency is completed between the relativized prepositional object and the stranded preposition. The following segment, segment 4, contains the RC VP-modifying adjunct phrase and is considered the spillover region. English PS prime sentences were split at the same points as in the target sentences, except these ended after the stranded preposition. English control sentences were split following the direct object NP and the subject NP. Segmentation points for target, prime, and control sentences are shown below in Table 4.

Table 4: *Segmentation for Spanish target and English prime and control sentences.*

<table>
<thead>
<tr>
<th>Segment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>target sentence</td>
<td>“Este es el serrucho que Eduardo cortó la rama con para hacer leña.”</td>
<td><em>This is the saw that Eduardo cut the branch with to make firewood.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>prime sentence</td>
<td><em>These are the scissors that Mary cut the paper with.</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>control sentence</td>
<td><em>This is the paper that Mary cut with the scissors.</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Spanish RC sentences were split into 4 segments: following the relativized object NP, the subject NP, and the indirect object for *que* sentences or the direct object for *dónde* sentences. In these sentences, segment 3 is also the critical region where the filler-gap dependency is completed between the relativized object and the RC verb, and contained the RC verb and either the indirect or direct object. The following segment, segment 4, contains the RC VP-modifying adjunct phrase and is considered the spillover region. Segmentation points for Spanish RC sentences are shown below in Table 5.
Table 5: Segmentation for Spanish RC sentences.

<table>
<thead>
<tr>
<th>Segment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>que sentence</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Estas son las camisas</td>
<td>que Sofía</td>
<td>regaló a la iglesia</td>
<td>el año pasado.</td>
<td></td>
</tr>
<tr>
<td>“These are the shirts”</td>
<td>“that Sofia”</td>
<td>“donated to the church”</td>
<td>“last year.”</td>
<td></td>
</tr>
<tr>
<td>donde sentence</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Este es el cuarto</td>
<td>donde Sara</td>
<td>puso su oficina</td>
<td>cuando se mudó.</td>
<td></td>
</tr>
<tr>
<td>“This is the room”</td>
<td>“where Sara”</td>
<td>“put her office”</td>
<td>“when she moved.”</td>
<td></td>
</tr>
</tbody>
</table>

**Fillers**

A total of 126 English and Spanish filler sentences were included in the priming experiment to disguise the purpose of the task and balance the total number of grammatical and ungrammatical sentences in each language. These sentences were comparable in length to the experimental stimuli and contained several complex structures. Ungrammatical Spanish and English sentences contained various grammatical violations, including morphosyntactic agreement errors and *wh*-movement violations (Sprouse & Hornstein, 2013).

Of the Spanish filler sentences, 13 of these began with *Este es “This is”,* so that the Spanish PS target sentences were not the only stimuli that started in this way. Similarly, 13 of the English filler sentences began with *This is.* Additionally, a set of 24 English sentence pairs that were published in Traxler et al.’s (2014) study of reduced relative clause priming in English were included as fillers so that the experimental sentences were not the only stimuli where identical syntactic structures were presented in succession with repetition of the verb.

It should be noted that Spanish pied-piped (PP) sentences were not included in the priming experiment in order to avoid drawing attention to the Spanish PS sentences and in order to increase the likelihood of finding cumulative priming effects. Previous structural priming studies have shown that priming effects may be short lived in experiments where the target structure and a possible competitor both occur while they have been found to be longer lived when there are no target structure competitors (e.g., Nitschke, Kidd, & Serratrice, 2010; and references therein).
Procedure

The cross-linguistic structural priming experiment was administered via a self-paced listening (aka, auditory moving window) experimental paradigm in order to capture differences in early stages of syntactic processing that could be attributed to the structure of the preceding English sentence (prime vs. control) (Mitchell, 2004; Papadopoulou, Tsimpli, & Amvrazis, 2014). While self-paced listening has not previously been used in a comprehension structural priming experiment, it is conceptually very similar to self-paced reading, which has been successfully used in several studies to measure structural priming during comprehension, and is based on the same assumption that longer response times indicate greater processing difficulty (Mitchell, 2004). The self-paced listening paradigm was selected in order to minimize differences in task effects between heritage speakers and late bilinguals. Since heritage speakers are known to vary considerably in their literacy training in the heritage language, self-paced listening was chosen over self-paced reading to avoid potential confounds due to differences in reading in Spanish and English.

Since the present study tests structural priming for an a priori ungrammatical structure, a comprehension task was chosen instead of a production task. Nearly all cross-linguistic structural priming studies so far have focused on production measures (but see Kidd et al., 2015; Weber & Indefrey, 2009), which lack the sensitivity to capture subtle but important clues about cross-linguistic structural priming. As Torres Cacoullos and Travis (2011) note that “…[i]n bilingual situations…strong normative pressures may inhibit bilinguals’ use of stigmatized features” (p. 6), which could potentially skew priming data obtained through production measures like elicitation tasks. Hsin et al. (2013) further justify the use of comprehension-based measures in their suggestion that adults may experience cross-linguistic priming of illicit structures but suppress the production of these structures. The use of online measures during comprehension avoids these potential issues by not requiring participants to produce any language or metalinguistic evaluations and furthermore provides a gradient measure of priming effects on processing. (See Polinsky (2016) for further discussion of potential issues with the use of production-based tasks in heritage language research and arguments calling for the use of comprehension-based measures.)

The self-paced listening experiment was delivered using E-Prime 2.0 software using a Tobii TX300 eye-tracking monitor and two external speakers located on either side of the monitor. Task evoked
pupillary response (TEPR) data were collected during the priming experiment to verify whether this measure is sensitive to structural priming effects but the TEPR analysis is not reported here. Subjects completed the priming experiment seated in a comfortable chair, 70 cm from the Tobii monitor and external speakers in a sound-proof testing booth. At the start of the experiment, the eye-tracking camera mounted to the Tobii monitor was calibrated and then subjects read instructions in English and completed a practice session of 10 trials. Following the practice session, subjects completed four experimental blocks, each lasting 10–15 minutes and were given short breaks between each block.

The instructions at the beginning of the experiment advised subjects that they would be listening to sentences in Spanish and English and that their task was to correctly answer true/false comprehension questions related to these sentences. Subjects were instructed to listen to each sentence for meaning and to answer the comprehension questions that appeared on screen at random throughout the task to their best ability. Participants were not asked to make any metalinguistic judgments during the priming experiment. Throughout the experiment, all text including instructions, fixation crosses, and comprehension questions appeared in size 18 white lettering against a black background.

During the experiment, all sentences were presented segment-by-segment and subjects controlled the rate of presentation by pressing the center button on a Serial Response (SR) Box to hear the next segment in each sentence. The sequence of audio and visual stimuli and timing of events during the presentation of each sentence is illustrated below in Table 6. At the start of each sentence, subjects saw OK in the center of the monitor and pressed the center button on the SR Box when they were ready to initiate the fixation procedure and presentation of the sentence. During the fixation procedure, subjects were required to focus on a fixation cross located in the center of the Tobii monitor for 2,000 ms. This ensured that subjects were within range of the Tobii eye-tracking cameras and also allowed their pupils to adjust to the screen brightness. The fixation period was followed by 500 ms of silence and then the segment 1 audio file began. Once the segment 1 audio file ended, subjects were required to press the center button on the SR Box to play the audio file for segment 2. This sequence of events was repeated for each segment in the sentence until subjects pressed the button following the final sentence segment, which elicited a 100 ms, 1 kHz tone that indicated the end of the sentence. After this tone, the fixation cross remained on screen for a 1,000 ms post-sentence fixation period, which was followed by a blank
screen that lasted for 1–10 seconds while the eye-tracking data saved to disk. At this point, after each target sentence and following 50% of the fillers, a true/false comprehension question related to the sentence appeared on the screen. For the Spanish PS target sentences, comprehension questions were designed to avoid drawing subjects’ attention to the stranded preposition. The comprehension questions were presented in the same language as the corresponding sentence. After subjects indicated their response by pressing the button labeled true or the button labeled false on the SR Box, the monitor was cleared for 2,000 ms before the OK appeared in the center of the screen prompting subjects to initiate the procedure for the next sentence.

Table 6: Sequence of visual and auditory stimuli and subject actions during presentation of sentences in the priming experiment.

<table>
<thead>
<tr>
<th>Duration</th>
<th>Presentation Stage / Auditory Stimulus</th>
<th>Visual Stimulus</th>
<th>Subject Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>variable</td>
<td>Sentence initiation</td>
<td>OK</td>
<td>Press button</td>
</tr>
<tr>
<td>2,000 ms</td>
<td>Fixation</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>500 ms</td>
<td>Pre-sentence silence</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>variable</td>
<td>Segment 1 audio</td>
<td>+</td>
<td>Press button</td>
</tr>
<tr>
<td>variable</td>
<td>Measure RT</td>
<td>+</td>
<td>Press button</td>
</tr>
<tr>
<td>variable</td>
<td>Segment 2 audio</td>
<td>+</td>
<td>Press button</td>
</tr>
<tr>
<td>variable</td>
<td>Segment 3 audio</td>
<td>+</td>
<td>Press button</td>
</tr>
<tr>
<td>variable</td>
<td>Segment 4 audio</td>
<td>+</td>
<td>Press button</td>
</tr>
<tr>
<td>100 ms</td>
<td>1 kHz tone</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>1,000 ms</td>
<td>Post-sentence fixation</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>variable</td>
<td>Save trial data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>variable</td>
<td>Comprehension question</td>
<td>Question text</td>
<td>Answer question</td>
</tr>
</tbody>
</table>

It is important to note that during the sentence presentation, the fixation cross remained on screen from the onset of the fixation period through the 1,000 ms post-sentence fixation period that followed the tone indicating the end of the sentence. Subjects were also instructed to keep their eyes

40 Since eye-tracking data were recorded during the initial fixation period, fixations that lasted longer than 2,000 ms increased the amount of data to be saved, which caused the variable lag times during data saving.
focused on the fixation cross while listening to each sentence, to keep their index or middle finger of their dominant hand on the center button of the SR Box during sentence presentation, and to use their index or middle finger to press the button to advance through the sentence segments. Subjects were able to readjust for comfort during the break between each sentence and between experimental blocks.

**BILINGUAL LANGUAGE PROFILE**

After completion of the priming experiment, the BLP was administered to collected information about subjects’ language dominance, exposure, use, proficiency, and attitudes for Spanish and English in order to answer RQ 2. The BLP is a short survey designed to measure language dominance for bilinguals through a set of questions pertaining to a subject’s language history, use, self-rated proficiency, and attitudes for both Spanish and English and has been tested for reliability, internal consistency, and validity (Gertken et al., 2014). It was designed to measure four dimensions of language dominance and provide a measure of language dominance, defined broadly “…in terms of relative language use, proficiency, and psychosocial identification” (Gertken, 2013, p. 71). While the overall BLP language dominance score was not included in the analysis, four variables related to language proficiency, exposure, and use were generated from BLP items for inclusion as predictor variables in the analysis for the priming and acceptability judgment results. Descriptions of these and other BLP variables are given below and they are summarized above in Table 1.

**Subjects**

All subjects who completed the priming experiment also completed the BLP at the end of the same testing session.

**Materials**

The Bilingual Language Profile is available online at: https://sites.la.utexas.edu/bilingual/.

**Procedure**

Subjects completed the BLP on paper on their own. After completion, responses were checked by the experimenter to ensure that all questions were answered following instructions. Following
collection, responses were typed in a spreadsheet and checked by another research assistant prior to analysis.

Results

Dominance

The BLP questionnaire provides a formula for calculating overall language dominance with possible dominance scores ranging from -218 to +218 with more positive scores indicating greater dominance in English compared to Spanish, more negative scores indicating greater dominance in Spanish compared to English, and scores closer to 0 indicating greater balance between Spanish and English. The language dominance scores calculated using the BLP formula indicated that all but one heritage speaker subject were dominant in English at the time of testing \((M = 47.49, SD = 31.15)\) and all late bilinguals were dominant in Spanish at the time of testing \((M = -66.75, SD = 31.2)\).

Proficiency

Subjects rated their proficiency separately for speaking, understanding, reading, and writing in both Spanish and English on a scale of 0–6, where 0 = not well at all and 6 = very well. From these responses, four composite scores for self-rated proficiency in English and Spanish were calculated: Spanish speaking and understanding \((PSU-S)\), Spanish reading and writing, English speaking and understanding \((PSU-E)\), English reading and writing. The composite score for speaking and understanding proficiency in each language was generated by averaging the self-ratings given for speaking and listing proficiency in each language; the composite score for reading and writing was generated by averaging the self-ratings given for reading and writing proficiency in each language. Heritage Spanish speakers reported higher proficiency in Spanish speaking and understanding \((PSU-S)\) \((M = 4.98, SD = 1.04)\) compared to proficiency in Spanish reading and writing \((M = 4.23, SD = 1.4)\) and higher proficiency in English speaking and understanding \((PSU-E)\) \((M = 5.93, SD = 0.18)\) and English

\[41\] The composite score for reading and writing proficiency in Spanish was calculated separately from speaking and listening as home language literacy skills are known to vary widely among heritage speakers who have had otherwise similar upbringings and differences in the frequency of occurrence in written and spoken language for the types of complex sentences tested in this study may have a measurable effect on their online processing.
reading and writing ($M = 5.89$, $SD = 0.29$) compared to the corresponding scores in Spanish. In contrast, late Spanish-English bilinguals reported higher proficiency in Spanish speaking and understanding ($PSU$) ($M = 5.93$, $SD = 0.23$) and Spanish reading and writing ($M = 5.84$, $SD = 0.32$) compared to scores for speaking and understanding English ($PSU$) ($M = 4.7$, $SD = 0.93$) and reading and writing English ($M = 4.7$, $SD = 1.07$).

**Exposure**

Three variables were created to represent different aspects of exposure to English. Two of these were created to represent the age at which subjects began acquiring English. The first predictor *English age of acquisition* ($AGE_{-E}$) measures the age at which subjects began acquiring English in any setting (including learning English as a foreign language in a classroom setting outside of the U.S.). This variable was collected via the BLP item: *At what age did you start learning English?* Possible responses to this question are whole numbers ranging from since birth (0 years old) to 20+ years old. Subjects who selected 20+ years old were asked to provide the age at which they began learning English in a supplemental questionnaire, and this response was used as the value for this predictor. Responses to this item for heritage speakers indicate that some subjects acquired Spanish and English simultaneously from birth while others began acquiring English later during childhood. All heritage speakers subjects began acquiring English by age 8 ($M = 4.07$, $SD = 2.35$). Within the late bilingual group, there is significant variation in English age of acquisition: while some subjects began learning English at age 2, others began learning English later in life, up to age 28 ($M = 14.64$, $SD = 6.75$).

The second predictor related to the age at which subjects began learning English is *age of arrival to the U.S.* ($AOA-US$). The reason for including this variable is that there may be different effects of exposure to English depending on whether exposure occurred in an immersion setting or a foreign language classroom setting. Subjects’ age of arrival to the U.S. was collected during the initial screening. For subjects who were born in the U.S., a value of 0 was used for this variable. The mean age of arrival to the U.S. for all heritage speakers was 1.7 years of age ($SD = 2.55$). While most of the heritage speaker subjects were born in the U.S., those who were born in a Spanish-speaking Latin American country were brought to the U.S. by age 8 ($M = 4.34$, $SD = 2.24$). In contrast, all late bilingual subjects were born in a
Spanish-speaking Latin American country and arrived to the U.S. between ages 15–34 ($M = 23.18$, $SD = 6.15$).

The third predictor for language exposure is length of residence in U.S. (LOR-US). This predictor was calculated for each subject by subtracting the age at which they arrived to the U.S. from their age at the time of testing. Length of residence in U.S. (LOR-US) is included to test the influence of differences in regular exposure to English in a naturalistic setting (as opposed to a foreign language classroom), independent of when subjects began learning English. While heritage speaker subjects report living in the U.S. between 13–39 years ($M = 22.82$, $SD = 6.06$), late bilingual subjects report living in the U.S. between 0.5 and 31 years ($M = 7.27$, $SD = 8.33$).

**Current Use**

To index current exposure levels to English and Spanish, the predictor proportion of daily interactions in Spanish (USE-S), was calculated by averaging over a subject’s responses to three BLP items: In an average week, what percentage of the time do you use the following languages [English, Spanish, other] with friends? In an average week, what percentage of the time do you use the following languages [English, Spanish, other] with family? In an average week, what percentage of the time do you use the following languages [English, Spanish, other] at school/work? For each item, subjects could select between 0%–100% (in increments of 10%) for each language. Within each item, the total percentage had to add up to 100%. The analysis of this predictor shows that some heritage speaker subjects currently interacted with friends, family, classmates, and co-workers in Spanish on average less than 10% of the time (0.07) while other subjects interacted with these people in Spanish over 60% of the time (0.67) on average ($M = 0.31$, $SD = 0.14$). For late bilingual subjects, the distribution of values for this predictor is similar, ranging from 0.20–0.80 ($M = 0.49$, $SD = 0.18$)

**ACCEPTABILITY JUDGMENT EXPERIMENT**

Following the priming experiment, subjects returned to the lab two weeks later to complete the acceptability judgment experiment. The purpose of this experiment was to provide a measure of subjects' perceptions of naturalness for Spanish PS target sentences without any effects of priming and to relate
the findings of the present study to the experimental findings in the heritage speaker literature based on offline, metalinguistic tasks.

Subjects

Of the 63 subjects who completed the priming experiment and BLP, a total of 49 (28 heritage Spanish speakers and 21 late Spanish-English bilinguals) returned to the lab to complete the acceptability judgment experiment.

Materials

The acceptability judgment experiment included only Spanish sentences. The same Spanish PS target sentences that were used in the priming experiment were presented auditorily as natural running speech in isolation (not phrase by phrase in two-sentence trials, as in the priming experiment). An additional set of Spanish PP control sentences derived from the PS target sentences were included in this task. The control sentences contained the same lexical items as the target sentences but exhibited the typical structure used to relativize a prepositional object, which involved movement of the preposition with the relative pronoun, as in (15a–b) below.

15. a. *Este es el serrucho con que Eduardo cortó la rama para hacer leña.*
   “This is the saw with which Eduardo cut the branch to make firewood.”

   b. *Esta es la tienda en que Gonzalo compró el pollo para cocinar la cena.*
   “This is the store in which Gonzalo bought the chicken to cook dinner.”

The acceptability judgment task also included a set of sentences that exhibited illicit wh-movement out of a complex NP island, as in (16a), which is ungrammatical in both Spanish and English, and grammatical control sentences, as in (16b). These sentences were included to provide a baseline measure of subjects’ ratings for structural violations in Spanish sentences involving wh-movement and to increase the diversity of structures presented in the judgment experiment (Cowart, 1997).
16. a. *Esta es la pistola que el ladrón admitió el hecho que su amigo escondió.*

**“This is the gun that the thief admitted the fact that his friend hid.”**

b. *Esta es la pistola que el ladrón admitió que su amigo escondió.*

“This is the gun that the thief admitted that his friend hid.”

The Spanish PS target and PP control sentences and complex NP island sentences were split into two lists and counterbalanced so that half of the con and en targets and half of the complex NP island sentences and their respective control sentences appeared in each list. The sentences in each list were interspersed with the same Spanish filler sentences used in the priming experiment and each list was pseudorandomized. Subjects encountered items from only one list.

**Procedure**

The acceptability judgment experiment was administered in the same testing booth as the priming experiment using the same software and hardware for stimulus presentation and data recording. At the start of the experiment, subjects read instructions in English on screen and completed a practice session. During the task, subjects listened to each sentence in its entirety and then made an acceptability judgment about the sentence using a 6-point Likert scale with endpoints labeled in Spanish as es natural “natural” and no es natural “unnatural”. Subjects pressed buttons labeled 1–6 on a keyboard to indicate their judgments. The numeric labeling of the scale was meant to ensure that subjects viewed the Likert scale as a continuous measure with each button representing an equal step in naturalness.

**ORAL FLUENCY TASK**

After the acceptability judgment task, subjects completed an oral fluency task in English and Spanish. A measure of oral fluency was included in the present study to obtain a more objective measure of subjects’ relative proficiency in Spanish and English. There are several methods that have been devised to measure bilingual language proficiency, however none is free of bias (Hulstijn, 2012). In the case of assessing language proficiency among heritage speakers, many standard measures based on written tests or vocabulary are particularly inappropriate given the widespread inconsistency in schooling and literacy training completed in the heritage language (Hulstijn, 2012; Valdés, 2005). Following previous research that has suggested that rate of speech is a relatively unbiased and reliable measure of
heritage language proficiency (Montrul, 2016; Polinsky, 2008; Polinsky & Kagan, 2007), subjects completed a story recall task in both languages during their second visit to the lab using two versions of the ‘Frog Story’ (Mayer, 1969). This task has been used in numerous studies to gauge oral fluency among child learner populations (Berman & Slobin, 1994; Strömqvist & Verhoeven, 2004) and has been used as a measure of heritage language proficiency in previous research (Albirini & Benmamoun, 2014; Polinsky, 2011).

Subjects

A total of 29 heritage speakers and 21 late bilinguals who completed the priming task return to the lab to complete the oral fluency task.42

Materials

Two versions of the Frog Story by Mercer and Marianna Mayer (1969) were used to elicit spontaneous speech: Frog, where are you? and One frog too many. The pictures from the story were copied into single pages and placed in a binder. The binder also contained instructions for reviewing the pictures and narrating the story.

Procedure

Following completion of the acceptability judgment task, subjects were given a short break and then completed the oral fluency task first in their dominant language (English for heritage speakers; Spanish for late bilinguals). Subjects completed the task in their other language approximately 30 minutes later, after completing a battery of working memory tasks, which were administered as part of a separate study are not reported here. Story versions were alternated between languages, so approximately half of the subjects in each group retold Frog, where are you? in English and One frog too many in Spanish while the other half retold the same stories in the other language. This task took place in the same testing booth used in the priming and acceptability judgment experiment.

42 One heritage speaker completed the oral fluency task but did not complete the acceptability judgment experiment.
During this task, subjects were given the binder containing the Frog Story images and instructions for the task. Subjects were told which language to narrate the story in at the beginning of the task and the written instructions for the task were provided in the language that the subject was asked to retell the story in. Subjects were instructed to spend 5 minutes looking through the Frog Story to familiarize themselves with the characters and the sequence of events and following this phase, they would be retelling the story aloud while they were recorded. Subjects were instructed to plan a narrative for the story during this phase but that they did not need to memorize the story since they would be flipping through the book as they narrated the events. Following this step, subjects were given five minutes to narrate the story aloud. Oral narratives were recorded with a CAD U2 headset microphone using Audacity recording and editing software, sampled at 44.1 kHz.

Results

Prior to analysis, the recordings were transcribed following these steps: First, each recording was automatically transcribed using Google Voice Typing. Second, each transcription generated by Google Voice Typing was checked for accuracy by hand and transcription errors were corrected. Next, lexical fillers that were omitted by Google Voice Typing (e.g., like, so, entonces “then”, bueno “OK”) were added to the transcript and, following this step, the final transcript including fillers was checked by hand once more by a different research assistant to confirm that it matched the audio recording verbatim.

The speech rate for each recording was analyzed as the number of words per minute (including fillers) starting from 30 seconds after the subject began speaking through the end of the recording (Albirini & Benmamoun, 2014; Polinsky, 2008). For heritage speakers, their English speech rate ranged from 80.94–186.12 words per minute \((M = 134.66, SD = 28.16)\) while their Spanish speech rate ranged from 72.71–184.44 words per minute \((M = 120.92, SD = 24.67)\). For late bilinguals, their English speech rate ranged from 69.88–179.19 words per minute \((M = 113.7, SD = 23.49)\) while their Spanish speech rate ranged from 72.29–172.71 words per minute \((M = 127.6, SD = 23.99)\).

In order to create a measure of relative fluency in Spanish and English that controlled for differences in overall speech rate between subjects during the task, the predictor of Spanish-English relative fluency (FLU-SE) was calculated by dividing each subject’s measure of Spanish fluency by their measure of English fluency and subtracting 1. For this variable, a score of 0 indicates equal speech rate.
for Spanish and English, while negative score indicates faster speech in English relative to Spanish, and a positive score indicates faster speech in Spanish relative to English. Among heritage speakers, Spanish-English relative fluency ranged from -0.37–0.13, with a mean of -0.09 (SD = 0.13) indicating overall faster speech in English relative to Spanish as a group. For late bilinguals, Spanish-English relative fluency ranged from -0.13–0.60, with a mean of 0.14 (SD = 0.18) indicating overall faster speech in Spanish relative to English for the group. These values are shown above in Table 1. It’s important to note that this variable does not indicate absolute fluency relative to other subjects, rather, it indicates the difference in fluency between Spanish and English for each subject.
CHAPTER 5: RESULTS

DATA ANALYSIS OVERVIEW

Subjects’ RTs collected during the priming experiment and the sentence ratings collected during the acceptability judgment task were analyzed using linear mixed-effects modeling with the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) in R (R Core Team, 2016). For the baseline syntactic processing analysis, the dependent variable was log-transformed RT at segment 3 and segment 4 in the Spanish RC sentences. For the cross-linguistic priming analysis, the dependent variable was log-transformed RT at segment 3 and segment 4 in the Spanish PS sentences. To address RQ 1, separate models were built for segments 3 and 4 that included condition (prime vs. control) and subject group (heritage speaker vs. late bilingual) as predictor variables. To address RQ 2, a second set of models was built separately for each group that included predictors variables from the BLP and oral fluency measure.

For the acceptability judgments analysis, the dependent variable was z-score-transformed ratings. A parallel set of models was built for these data: The first model included condition (grammatical vs. ungrammatical) and subject group (heritage speakers vs. late bilinguals) as predictor variables to determine whether (ungrammatical) Spanish PS sentences were rated differently from their (grammatical) PP counterparts. The second model also included predictor variables from the BLP and oral fluency task to determine if they had any influence on acceptability ratings.

COMPREHENSION QUESTION ACCURACY

Before analyzing the RT data, comprehension question accuracy was analyzed to ensure that subjects were paying attention during the priming experiment. This analysis showed that all subjects answered the comprehension questions with at least 70% accuracy (M = 87.2, SD = 4.83) across all stimuli, which indicates that subjects were paying attention to the sentences during the task. Comprehension question accuracy is shown below by group by stimulus type in Table 7.
Table 7: Comprehension question accuracy by stimulus type for heritage Spanish speakers and late bilinguals. Standard deviations are indicated in parentheses.

<table>
<thead>
<tr>
<th>Stimulus Type</th>
<th>HS</th>
<th>N = 41 (31 female)</th>
<th>LB</th>
<th>N = 22 (11 female)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Spanish Target PS <em>con</em> sentences</td>
<td>92.07 (7.67)</td>
<td>75.00 – 100</td>
<td>90.15 (9.5)</td>
<td>66.67 – 100</td>
</tr>
<tr>
<td>Spanish Target PS <em>en</em> sentences</td>
<td>89.58 (9.87)</td>
<td>63.64 – 100</td>
<td>91.32 (10.67)</td>
<td>63.64 – 100</td>
</tr>
<tr>
<td>Spanish RC sentences</td>
<td>98.29 (4.95)</td>
<td>80.00 – 100</td>
<td>95.91 (7.34)</td>
<td>70.00 – 100</td>
</tr>
</tbody>
</table>

Particularly important for the baseline syntactic processing analysis, accuracy rates for RC sentences were very high among heritage speakers (\(M = 98.29, \ SD = 4.95\)) and late bilinguals (\(M = 95.91, \ SD = 7.34\)). These results indicate that individuals in both groups accurately comprehended these sentences. While the comprehension accuracy for Spanish PS sentences is somewhat lower compared to Spanish RC sentences, it is important to recall that Spanish PS sentences exhibited a structural violation, which is expected to lower comprehension accuracy.

BASELINE SYNTACTIC PROCESSING RESULTS

The baseline syntactic processing analysis was conducted in order to understand how heritage speakers and late bilinguals processed Spanish grammatical object RC sentences and serves as a reference point for interpreting the cross-linguistic priming results.

Data Preparation

RT was measured for each segment in the RC sentences as the time between the offset of that segment’s recording and the moment the subject pressed the button on the SR box to hear the next segment. For the analysis, RT was log transformed following standard procedures in psychology and psycholinguistics (Baayen & Milin, 2010). Log-transformed RTs were trimmed by identifying outliers by subject by segment (1–4) for RC sentences and removing these data points from the analysis. Outlier
removal affected 5.36% of RC sentence data points across subjects and segments.\(^{43}\) The number of data points removed and corresponding percentage of total data points are shown by segment across groups in Table 8, below.

Table 8: Data points removed (outliers) from RC sentences as a percentage of total data points across group by segment.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Total Samples</th>
<th>% Outliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>630</td>
<td>5.56</td>
</tr>
<tr>
<td>2</td>
<td>630</td>
<td>5.56</td>
</tr>
<tr>
<td>3</td>
<td>630</td>
<td>3.97</td>
</tr>
<tr>
<td>4</td>
<td>630</td>
<td>6.35</td>
</tr>
</tbody>
</table>

Results

The RT analysis reported below included only those 50 subjects (29 heritage speakers, 21 late bilinguals) who also completed the oral fluency task. A total of 12 heritage speakers and 1 late bilingual who completed the priming experiment but did not complete the oral fluency task were excluded from the analysis. RTs were analyzed at RC sentence segment 3 (the critical sentence region) because this is where the filler-gap dependency involving the relativized NP is completed. RTs at segment 4 (the spillover region) were also analyzed because syntactic processing difficulties often register downstream from where they occur.\(^{44}\) For this and all RT analyses reported here, decreases in RT are interpreted as

\(^{43}\) Self-paced reading studies typically remove response times less than 80–100 ms as these times indicate that subjects have not read the stimuli (Baayen & Milin, 2010). This is necessary in in self-paced reading experiments since the written stimuli have no temporal dimension, and response time measurement must begin from the onset of stimulus presentation. However, the stimuli used in the self-paced listening experiment of the present study unfolded over time and subjects were required to wait until each audio file had finished to press the button to begin the next sentence segment. Since subject were able to process each sentence segment before they could press the button to advance, no minimum RT threshold was used during data trimming for the present analysis.

\(^{44}\) While sentence-final ‘wrap-up’ effects that have been commonly reported in psycholinguistic studies have, in some cases, been attributed to later processes such as semantic integration, the analyses for sentence-final segments reported here will not be interpreted in terms of the processes. Since in the stimuli examined here, the spillover region (the sentence segment following the critical region) is also the final segment in the sentence, it is not possible to determine whether any processing differences observed at the sentence-final segments are due to effects of filler-gap completion during the critical region or from sentence wrap up effects. The most conservative option given this limitation is to assume that any processing effects that occur at the sentence-final segments reflect syntactic processing during the critical region itself.
an indication of facilitated syntactic processing while increases in RT are interpreted as an indication of more difficult syntactic processing.

**Heritage Speakers vs. Late Bilinguals**

Mean trimmed RTs (excluding outliers) for RC sentences are plotted by segment by group below in Figure 1 and the corresponding data are shown in Table 10. The segmentation for RC sentences is shown in Table 9.

![Figure 1](image)

> Figure 1: Mean RTs for RC sentences by segment for heritage speakers and late bilinguals. Error bars represent 95% confidence intervals.

<table>
<thead>
<tr>
<th>Segment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>que sentence</td>
<td><em>Estas son las camisas“</em></td>
<td><em>que Sofia“</em></td>
<td><em>regaló a la iglesia“</em></td>
<td><em>el año pasado.“</em></td>
</tr>
<tr>
<td>donde sentence</td>
<td><em>Este es el cuarto“</em></td>
<td><em>donde Sara“</em></td>
<td><em>puso su oficina“</em></td>
<td><em>cuando se mudó.“</em></td>
</tr>
</tbody>
</table>

Table 9: **Segmentation for RC sentences.**
Table 10: Mean raw RTs for RC sentences by segment for heritage speakers (n = 29) and late bilinguals (n = 21).

<table>
<thead>
<tr>
<th>Segment</th>
<th>HS</th>
<th>SD</th>
<th>LB</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>542.27</td>
<td>547.53</td>
<td>526.63</td>
<td>411.86</td>
</tr>
<tr>
<td>2</td>
<td>446.73</td>
<td>232.70</td>
<td>453.24</td>
<td>303.05</td>
</tr>
<tr>
<td>3</td>
<td>553.14</td>
<td>420.24</td>
<td>506.48</td>
<td>392.44</td>
</tr>
<tr>
<td>4</td>
<td>817.80</td>
<td>1159.26</td>
<td>1186.38</td>
<td>1378.32</td>
</tr>
</tbody>
</table>

Figure 1 shows an overall similar pattern of RTs for heritage speakers and late bilinguals across RC sentence segments 1–4, although RTs for late bilinguals are visibly higher at segment 4 compared to heritage speakers. Separate linear mixed-effects models were generated for segment 3 and segment 4 to test the effects of group (late bilingual vs. heritage speaker) on the dependent variable, log-transformed RT. The mixed-effects model for each segment contained the following fixed effects: log-transformed trial number (TRIAL), group (GROUP), trial rank (RANK), and the interaction between GROUP and RANK.

The predictor GROUP was included to test whether heritage speakers show differences in processing RC sentences compared to late bilinguals and RANK was included to test the effects of cumulative priming on the syntactic processing of these sentences. Previous studies have shown cumulative priming effects in which structures that are a considered difficult to process or unexpected become easier to process over the course of an experiment due to repeated exposure (Fine & Jaeger, 2016; Kaschak & Glenberg, 2004). TRIAL was included to control for changes in RT over the course of the experiment due to task adaptation (Baayen, 2008). Fine and Jaeger (2013) motivate the distinction between trial order and trial rank and justify the inclusion of both predictors in structural priming experiments to tease apart the effects of task adaptation from the effects of cumulative priming of the structure in question. The log transformation of TRIAL follows from their suggestions on separating the effects of these two variables. For all model estimates, predictor significance was tested with the lmerTest package (Kuznetsova, Brockhoff, & Christensen, 2017) in R with maximum likelihood t-tests using Satterthwaite approximations for degrees of freedom. The inclusion of the predictor variables in each model was justified using likelihood ratio tests that compared the goodness of fit of model including fixed effects to a model containing only the random effects structure (Baayen, 2008).
The `GROUP` variable was contrast coded (aka sum coded) for the segment 3 and segment 4 models to reduce collinearity between fixed effects involving this predictor. Following standard practice in mixed-effects modeling of similar psycholinguistic data, the predictor variables `TRIAL` and `RANK` were mean centered to avoid collinearity with the model intercept (Baayen, 2008). With this coding scheme, the coefficient for the model intercept represents the grand mean log RT at the mean trial number and mean rank number. For the predictor `GROUP`, the coefficient represents the difference in mean log-transformed RT between the comparison level (indicated in parentheses) and the grand mean log RT at the mean trial number and mean rank number.

The segment 3 model estimates for RC sentences are shown below in Table 11. The segment 3 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge (Barr, Levy, Scheepers, & Tily, 2013): random intercepts for subjects and items, as well as by-subject and by-item random slopes for `RANK` and `TRIAL`. In addition to the expected high correlation between the fixed effects of `RANK` and `TRIAL` (\( r = -.86 \)), there was moderate correlation between the intercept and both `RANK` (\( r = -.45 \)) and `TRIAL` (\( r = .38 \)). Correlations between all other fixed effects were less than ±0.40, indicating low collinearity among these fixed effects.

The segment 3 model captured 50% of the variance in log RT (\( R^2 = .50 \)) and the likelihood ratio test justified the inclusion of the fixed effects in this model (\( \chi^2 (4) = 11.99, p = .02 \)). The coefficient estimate for `TRIAL` indicates a significant effect of trial number on log RT at segment 3: For each unit increase in trial number, log RT decreased (\( \beta = -0.12, SE = 0.05, p = .02 \)), indicating overall faster response times at segment 3 as the experiment progressed. There were no other significant effects for `RANK`, `GROUP`, or the interaction between `RANK` and `GROUP`, which suggests that segment 3 RTs were not

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45 Treatment coding (aka dummy coding) of predictor variables in mixed-effects modeling often leads to collinearity between the predictor variables, the intercept, and interactions involving the predictor variables. This was also true for the present analysis. The initial set of models constructed with treatment coding for `GROUP` revealed a moderate correlation between `GROUP` and the interaction of `RANK` and `GROUP` (\( r = .46 \)) and a high correlation between `GROUP` and the intercept (\( r = -.65 \)). For this reason, the `GROUP` variable was recoded with contrast coding which resulted in low correlations between the all fixed effects and interactions in this model (except for the fixed effects of `RANK` and `TRIAL`, which were highly correlated). Fixed effects correlations are reported separately for all models in this chapter.

46 Barr et al. (2013) argue that mixed-effects models generated for hypothesis testing should include the maximal effects structure in order to be able to generalize the results of the sample to the population.
different between heritage speakers and late bilinguals and they did not change significantly following repeated exposure to the RC sentences.

Table 11: RC sentence segment 3 linear mixed-effects model estimates for heritage speakers and late bilinguals. The intercept represents grand mean log RT at the mean trial number and mean rank number.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>6.067</td>
<td>0.07</td>
<td>84.49</td>
<td>&lt;.001 ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.120</td>
<td>0.05</td>
<td>-2.49</td>
<td>0.02 *</td>
</tr>
<tr>
<td>RANK</td>
<td>0.012</td>
<td>0.05</td>
<td>0.23</td>
<td>0.82</td>
</tr>
<tr>
<td>GROUP(LB)</td>
<td>-0.040</td>
<td>0.11</td>
<td>-0.38</td>
<td>0.71</td>
</tr>
<tr>
<td>RANK:GROUP(LB)</td>
<td>-0.016</td>
<td>0.05</td>
<td>-0.32</td>
<td>0.75</td>
</tr>
</tbody>
</table>

† p < .1    *p < .05    ** p < .01    ***p < .001

The segment 4 model estimates for the RC sentences are shown below in Table 12. The segment 4 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge (Barr et al., 2013): random intercepts for subjects and items, as well as by-subject and by-item random slopes for RANK and TRIAL. Aside from the expected high correlation between the fixed effects of RANK and TRIAL (r = -.86), correlations between all other fixed effects were less than ±0.15, indicating low collinearity among model fixed effects.

Table 12: RC sentence segment 4 linear mixed-effects model estimates for heritage speakers and late bilinguals. The intercept represents grand mean log RT at the mean trial number and mean rank number.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>6.458</td>
<td>0.09</td>
<td>72.25</td>
<td>&lt;.001 ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.194</td>
<td>0.07</td>
<td>-2.61</td>
<td>0.02 *</td>
</tr>
<tr>
<td>RANK</td>
<td>-0.051</td>
<td>0.07</td>
<td>-0.72</td>
<td>0.48</td>
</tr>
<tr>
<td>GROUP(LB)</td>
<td>0.308</td>
<td>0.16</td>
<td>1.97</td>
<td>0.05 †</td>
</tr>
<tr>
<td>RANK:GROUP(LB)</td>
<td>-0.016</td>
<td>0.08</td>
<td>-0.21</td>
<td>0.83</td>
</tr>
</tbody>
</table>

† p < .1    *p < .05    ** p < .01    ***p < .001

The segment 4 model captured 53% of the variance in log RT ($R^2 = .53$) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (4) = 16.67, p < .01$). The coefficient estimate for TRIAL indicates a significant effect of trial number on log RT at segment 4: For each unit increase in trial number, log RT decreased ($\beta = -0.194, SE = 0.07, p = .002$), indicating overall faster
response times at segment 4 as the experiment progressed. Unlike the model estimates for segment 3, there was a marginally significant main effect of GROUP ($\beta = 0.308$, $SE = 0.16$, $p = .055$) which confirms that RTs at segment 4 were significantly longer for late bilinguals than for heritage speakers. There were no significant effects for RANK or the interaction between RANK and GROUP, which suggests that repeated exposure to RC sentences did not consistently affect segment 4 RTs for either group.

**Language Exposure, Use, and Proficiency**

To determine whether individual differences in language exposure, use, and proficiency had a significant influence on syntactic processing of the RC sentences, log RTs at segments 3 and 4 were analyzed separately for heritage speakers and late bilinguals. The predictor variables included in these mixed-effects models were selected based on the studies reviewed in Chapter 2 and Chapter 3, which have suggested that these variables play a role in both heritage language acquisition and bilingual syntactic processing. The specific variables selected for each group are detailed below.

**Heritage Speakers**

Two mixed-effects models were created to analyze the effects of individual differences in language exposure, use, and proficiency on heritage speakers’ RTs for segments 3 and 4. Prior to constructing these models, correlations between these predictor variables were analyzed to determine whether any were redundant and could be removed or combined. The purpose of this step was to reduce the chances of multicollinearity between model fixed effects, which has the potential to inflate standard error calculations and increase the chances of Type 2 errors. Collinearity between fixed-effects occurs commonly in mixed-effects modelling and the chances of fixed effects being collinear increases in models with many predictors and predictors that are conceptually related. The predictors considered for the heritage speaker models reported below include: age of English acquisition (AGE-E); length of residence in the U.S. (LOR-US); current proportion of daily interactions in Spanish (USE-S); self-reported proficiency speaking and understanding Spanish (PSU-S); and Spanish-English oral fluency ratio (FLU-SE). Spearman’s correlation coefficient was calculated between predictor variables using the `cor()` function in R. This analysis revealed moderate correlations between several predictor variables, shown below in Table 13.
Table 13: Spearman’s correlation coefficient between language experience and ability predictor variables for heritage speakers (n = 29). Moderate correlations are in bold.

<table>
<thead>
<tr>
<th></th>
<th>AGE-E</th>
<th>LOR-US</th>
<th>USE-S</th>
<th>FLU-SE</th>
<th>PSU-S</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE-E</td>
<td>1</td>
<td>-.57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOR-US</td>
<td>-.57</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USE-S</td>
<td>.35</td>
<td>-.08</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLU-SE</td>
<td>.22</td>
<td>-.22</td>
<td>.13</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>PSU-S</td>
<td>.33</td>
<td>-.39</td>
<td>.50</td>
<td>.12</td>
<td>1</td>
</tr>
</tbody>
</table>

Not surprisingly, AGE-E and LOR-US showed a moderate negative correlation ($r = -.57$), reflecting the fact that heritage speakers who were also exposed to English at an earlier age (smaller value for AGE-E) have typically been living in the U.S. for longer (larger value for LOR-US). Also, somewhat unsurprising, was a moderate positive correlation ($r = .50$) between USE-S and PSU-S. This correlation reflects the fact that heritage speakers who currently use more Spanish with friends, family, and at school or work self-report higher proficiency in speaking and understanding Spanish compared to heritage speakers who use less Spanish in daily interactions.

To reduce collinearity between these fixed effects in the models for segments 3 and 4, the predictor LOR-US was residualized and the predictor PSU-S was removed from the model. Removal of PSU-S is justified since a more objective measure of relative Spanish proficiency, FLU-SE, which shows weak or very weak correlations with the other predictors is retained in the model. Since previous heritage language research suggests that age of exposure to the dominant language is related to behavioral differences in use of the heritage language (e.g., Pascual y Cabo & Soler, 2015), AGE-E was retained in the model. Research has also suggested that not only age of exposure to the dominant language, but also amount of exposure to the dominant language can affect the heritage language. In order to model the effects of exposure to English (operationalized as LOR-US) that are not shared with age of exposure to English, the predictor LOR-US was replaced with the residual values of regressing LOR-US onto AGE-E. The residuals of this regression represent the variation in LOR-US that isn’t linearly related to AGE-E (Jaeger & Kuperman, 2009). A comparison of the correlations between residualized LOR-US and AGE-E and the original LOR-US variable indicates that residualized LOR-US is highly correlated with the original variable ($r = .73$) while being simultaneously uncorrelated with AGE-E ($r = .09$). In the models reported below, effects
related to the residualized LOR-US predictor represent the unique influence of amount of exposure to English on log RT beyond the variation in log RT that is captured by the predictor for age of exposure to English.

After removing PSU-S and residualizing LOR-US, each of the predictors related to language experience was mean centered to reduce collinearity: AGE-E, LOR-US, USE-S, FLU-SE. The mixed-effects model for each segment also contained the same predictors that were included in the by-group analysis reported above (excluding GROUP): log-transformed trial number (TRIAL) and trial rank (RANK). As in the by-group analysis reported above, the predictor variables RANK and TRIAL were also mean centered to avoid collinearity with the model intercept. The dependent variable for each model was log RT and each model included the maximal random effects structure that allowed the model to converge (Barr et al., 2013).

With this coding scheme, the coefficient for the segment 3 and segment 4 model intercepts represents the GRAND MEAN log RT at the mean value for each centered predictor: RANK, TRIAL, AGE-E, LOR-US, USE-S, and FLU-SE. For each centered predictor, the coefficient represents the change in log RT for each unit increase in the predictor.

Model estimates for segment 3 are shown below in Table 14. The segment 3 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for RANK and TRIAL. Except for the high correlation between the fixed effects of RANK and TRIAL ($r = -0.86$), correlations between all fixed effects were less than ±0.4, indicating low collinearity among model fixed effects.

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47 It should be noted that while centering continuous predictor variables reduces the collinearity between fixed effects, this transformation preserves the fixed-effects coefficient estimates relative to an identical model with uncentered predictors (Baayen, 2008; Jaeger, 2011).

48 While the full model containing all fixed effects and the random effects structure that included the by-items random correlation parameter successfully converged, the null model that included only the random effects structure failed to converge when the by-item random correlations parameter was included. In order to compare the goodness of fit between the full and null model, the by-item random correlations parameter was omitted from the segment 3 model for heritage speakers. Barr et al. (2013) suggest that removal of the random correlations parameter is typically the best low-impact strategy for dealing with failures of model convergence. Their simulation showed similar performance between models with maximal random effects structures (including random correlations) and models that differed only in the omission of the random correlations parameter. In the case of the RC sentence segment 3 model for heritage speakers, the full model that omitted the by-items random correlation parameter was qualitatively identical to the full model containing this parameter.
The segment 3 model for heritage speakers captured 54\% of the variance in log RT ($R^2 = .54$) and the significant outcome of the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (10) = 18.64, p < .05$). Unlike in the by-group segment 3 model, TRIAL was not significant, however, there was a significant effect for the predictor FLU-SE ($\beta = 1.076$, $SE = 0.5$, $p = 0.04$) which indicates an increase in log RT with each unit increase in Spanish-English fluency ratio. Independent of when the RC sentence was encountered in the experiment, log RT at RC sentence segment 3 was significantly longer for heritage speakers who had higher fluency in Spanish than English compared to heritage speakers who had higher fluency in English than Spanish.

Table 14: RC sentence segment 3 model estimates for heritage speakers (n=29). The intercept represents the grand mean log RT at the mean value for each centered predictor.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>6.122</td>
<td>0.08</td>
<td>78.71</td>
<td>&lt;.001  ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.055</td>
<td>0.05</td>
<td>-1.03</td>
<td>0.33</td>
</tr>
<tr>
<td>RANK</td>
<td>-0.042</td>
<td>0.05</td>
<td>-0.76</td>
<td>0.47</td>
</tr>
<tr>
<td>AGE-E</td>
<td>-0.022</td>
<td>0.03</td>
<td>-0.76</td>
<td>0.45</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.023</td>
<td>0.01</td>
<td>1.61</td>
<td>0.12</td>
</tr>
<tr>
<td>USE-S</td>
<td>0.352</td>
<td>0.47</td>
<td>0.75</td>
<td>0.46</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>1.076</td>
<td>0.50</td>
<td>2.14</td>
<td>0.04    *</td>
</tr>
<tr>
<td>RANK:AGE-E</td>
<td>-0.019</td>
<td>0.01</td>
<td>-1.52</td>
<td>0.14</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.008</td>
<td>0.01</td>
<td>-1.17</td>
<td>0.25</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>0.209</td>
<td>0.21</td>
<td>0.98</td>
<td>0.33</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>-0.362</td>
<td>0.23</td>
<td>-1.58</td>
<td>0.12</td>
</tr>
</tbody>
</table>

† $p < .1$  * $p < .05$  ** $p < .01$  ***$p < .001$

Model estimates for segment 4 are shown below in Table 15. The segment 4 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for RANK and TRIAL. Except for the high correlation between the fixed effects of RANK and TRIAL ($r = -.81$), correlations between all fixed effects were less than ±0.4, indicating low collinearity among model fixed effects.

The segment 4 model for heritage speakers captured 49\% of the variance in log RT ($R^2 = .49$) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (10) = 22.62, p = .01$). As
in the segment 3 model, the coefficient estimate for TRIAL is not significant at segment 4 for heritage speakers ($\beta = -0.105, SE = 0.08, p = .17$). As expected, given the segment 3 model estimates, the marginally significant coefficient for FLU-SE indicates longer RTs at segment 4 for heritage speakers who have higher fluency in Spanish compared to English ($\beta = 1.379, SE = 0.71, p = 0.06$). In addition, there was a significant main effect of AGE-E ($\beta = -0.091, SE = 0.04, p = 0.03$) indicating that RTs were faster at segment 4 for heritage speakers who were exposed to English later in childhood compared to heritage speakers who were exposed to English from birth. No other main effects or interactions were significant for this model.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>6.317</td>
<td>0.10</td>
<td>66.12</td>
<td>&lt;.001***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.105</td>
<td>0.08</td>
<td>-1.39</td>
<td>0.17</td>
</tr>
<tr>
<td>RANK</td>
<td>-0.115</td>
<td>0.08</td>
<td>-1.52</td>
<td>0.13</td>
</tr>
<tr>
<td>AGE-E</td>
<td>-0.091</td>
<td>0.04</td>
<td>-2.23</td>
<td>0.03*</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.018</td>
<td>0.02</td>
<td>0.88</td>
<td>0.38</td>
</tr>
<tr>
<td>USE-S</td>
<td>0.523</td>
<td>0.67</td>
<td>0.78</td>
<td>0.44</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>1.397</td>
<td>0.71</td>
<td>1.96</td>
<td>0.06†</td>
</tr>
<tr>
<td>RANK:AGE-E</td>
<td>-0.020</td>
<td>0.02</td>
<td>-0.92</td>
<td>0.36</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.012</td>
<td>0.01</td>
<td>-1.08</td>
<td>0.28</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>-0.053</td>
<td>0.34</td>
<td>-0.16</td>
<td>0.88</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>-0.184</td>
<td>0.36</td>
<td>-0.52</td>
<td>0.61</td>
</tr>
</tbody>
</table>

† $p < .1$  *$p < .05$  **$p < .01$  ***$p < .001$

Late Bilinguals

Following the same procedure in the heritage speaker analysis, two mixed-effects models were created to analyze the effects of differences in language exposure, use, and proficiency on late bilinguals’ RTs for RC sentence segments 3 and 4. Prior to constructing these models, correlations between the predictor variables related to language experience and ability were analyzed to determine whether any were redundant and could be removed or combined. These predictors were nearly identical to those
analyzed for heritage speakers: age of arrival to the U.S. (AOA-US), length of residence in the U.S. (LOR-US); current proportion of daily interactions in Spanish (USE-S); self-reported proficiency speaking and understanding English (PSU-E); and Spanish-English oral fluency ratio (FLU-SE). Spearman’s correlation coefficient was calculated between predictor variables using the cor() function in R. This analysis revealed moderate to high correlations between several predictor variables, shown below in Table 16.

Table 16: Spearman’s correlation coefficients between language experience and ability predictor variables for late bilinguals (n = 21). Moderate and high correlations are in bold.

<table>
<thead>
<tr>
<th></th>
<th>AOA-US</th>
<th>LOR-US</th>
<th>USE-S</th>
<th>FLU-SE</th>
<th>PSU-E</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOA-US</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOR-US</td>
<td>-0.30</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USE-S</td>
<td>-0.02</td>
<td>-0.39</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLU-SE</td>
<td>0.09</td>
<td>-0.59</td>
<td>0.61</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>PSU-E</td>
<td>0.29</td>
<td>0.14</td>
<td>-0.33</td>
<td>-0.45</td>
<td>1</td>
</tr>
</tbody>
</table>

Like the correlation observed between FLU-SE and PSU-S for heritage speakers, the analysis of predictors for late bilinguals showed a moderate negative correlation ($r = -0.45$) between FLU-SE and PSU-E. For late bilinguals, the correlation is negative due to the inclusion of self-rated proficiency in English as a predictor (rather than self-rated proficiency in Spanish, used for heritage speakers), which indicates that late bilinguals who reported higher English proficiency also had oral fluency rates in English that were more similar to their oral fluency rates in Spanish. Unlike for heritage speakers, among late bilinguals, the predictor USE-S showed a high positive correlation ($r = 0.61$) with FLU-SE and the predictor LOR-US showed a

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49 For late bilinguals, AOA-US was used to represent age of English acquisition rather than the self-reported AGE-E variable, which was used for heritage speakers. The reason is that for late bilinguals, AOA-US represents the first exposure to English in a naturalistic setting, which is equivalent to the same type of exposure represented by AGE-E for heritage speakers. Many late bilingual subjects indicated that they attended some English language classes during school in their home countries and reported their age during these classes as the age at which they began learning English (AGE-E). The exposure to English input received in a foreign language classroom is very different compared to English input encountered in a naturalistic setting. Thus, in order to maintain comparability between the predictor variables reflecting age of English acquisition in the heritage speaker and late bilingual analyses, the variable AOA-US was used for late bilinguals instead of AGE-E.

50 The predictor PSU-E was included for late bilinguals instead of the predictor PSU-S, which was included for heritage speakers. The reason for the difference between groups is that there was little variation in self-reported Spanish proficiency among late bilinguals, while the opposite was true for heritage speakers, who showed very little variation in self-reported English proficiency.
moderate negative correlation ($r = -0.59$) with \textit{FLU-SE}. The positive correlation between \textit{USE-S} and \textit{FLU-SE} reflects the fact that late bilinguals who currently use more Spanish with friends, family, and at school or work had a larger difference in oral fluency rates for Spanish and English compared to late bilinguals who use less Spanish in daily interactions (and therefore more English), who had oral fluency rates that were more similar between English and Spanish. The negative correlation between \textit{LOR-US} and \textit{FLU-SE} is due to the fact that late bilinguals who have been living longer in the U.S. also had relatively similar oral fluency rates for Spanish and English, compared to late bilinguals who had been living in the U.S. for less time and had higher fluency in Spanish compared to English.

Since \textit{FLU-SE} is the common variable in each of these correlations, the easiest way to reduce collinearity between these fixed effects in the models for segments 3 and 4 would be to remove \textit{FLU-SE} from the models. However, the analysis for heritage speakers reported in the previous section indicated that \textit{FLU-SE} was a significant predictor of RT at RC sentence segments 3 and 4. Given the potential importance of this predictor in accounting for variation in RTs for late bilinguals, the ideal solution would be to include \textit{FLU-SE} in the models in some form. To this end, \textit{FLU-SE} was replaced with the residual values of regressing \textit{FLU-SE} onto \textit{USE-S}. The residuals of this regression represent the variation in \textit{FLU-SE} that isn’t linearly predicted by \textit{USE-S}. A comparison of the correlations between residualized \textit{FLU-SE} and \textit{USE-S} and the original \textit{FLU-SE} variable indicates that residualized \textit{FLU-SE} is highly correlated with the original \textit{FLU-SE} variable ($r = 0.73$) while being simultaneously uncorrelated with \textit{USE-S} ($r = -0.02$). In addition, this transformation reduced the correlation between residualized \textit{FLU-SE} and \textit{LOR-US} ($r = -0.46$) to a moderate level. In the models reported below, the residualized \textit{FLU-SE} predictor represents the unique influence of Spanish-English oral fluency ratio on log RT beyond the variation in log RT that is predicted by proportion of Spanish used in daily interactions. To maintain further consistency between the heritage speaker and late bilingual models, the predictor \textit{PSU-E} was also removed from the models reported below. As was the case for heritage speakers, removal of \textit{PSU-E} is justified since a more objective measure of relative Spanish proficiency, \textit{FLU-SE} is retained in the model.

After removing \textit{PSU-E} and residualizing \textit{FLU-SE}, each of the predictors related to language experience was mean centered to reduce collinearity: \textit{AOA-US}, \textit{LOR-US}, \textit{USE-S}, \textit{FLU-SE}. The mixed-effects model for each segment contained the same experiment-related fixed effects that were included in the by-
group and heritage speaker analyses reported above: trial rank (RANK) and log-transformed trial number (TRIAL). As in the by-group and heritage speaker analyses, each of the continuous predictor variables (AOA-US, LOR-US, USE-S, FLU-SE) was mean centered to avoid collinearity between model fixed effects. Each model included the maximal random effects structure that allowed the model to converge (Barr et al., 2013). With this coding scheme, the coefficient for the model intercept represents the grand mean log-transformed RT at the mean value for each centered predictor. For each centered predictor, the coefficient estimate represents the change in log-transformed RT for each unit increase in the predictor.

Model estimates for RC sentence segment 3 are shown below in Table 17. The segment 3 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for RANK and TRIAL. The likelihood ratio test for the segment 3 model for late bilinguals indicated that inclusion of the all fixed effects (TRIAL, RANK, AOA-US, LOR-US, USE-S, FLU-SE) did not improve the fit of this model over the null model that included only random effects ($\chi^2 (10) = 13.28, p = .21$). To address this lack of significance, fixed effects were systematically removed and each resulting model was compared to the null model. This process resulted in a final model that contained only the fixed effects of TRIAL, RANK, AOA-US and USE-S, which captured 53% of the variance in log RT ($R^2 = .53$) and was a marginally significant improvement over the fit of the null model ($\chi^2 (6) = 11.82, p = .06$). In addition to the expected high correlation between the fixed effects of RANK and TRIAL ($r = -.89$), there were high correlations between the intercept and TRIAL ($r = .61$) and RANK ($r = -.65$). Correlations between all other fixed effects were less than ±0.4, indicating low collinearity among these fixed effects.

Similar to the RC sentence segment 3 by-group analysis, the effect TRIAL was significant in this model ($\beta = -0.258, SE = 0.11, p = .03$). No other main effects or interactions reached significance.

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51 In comparison to the reduced model, the full model containing all fixed effects produced fixed-effects coefficients that were qualitatively identical. In the full model, TRIAL also reached significance ($\beta = -0.250, SE = 0.10, p = .03$) and no other effects reached significance.
Table 17: RC sentence segment 3 linear mixed-effects model estimates for late bilinguals (n=21). The intercept represents the grand mean log RT at the mean value for each centered predictor.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>5.977</td>
<td>0.11</td>
<td>56.35</td>
<td>&lt;.001   ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.258</td>
<td>0.11</td>
<td>-2.44</td>
<td>0.03    *</td>
</tr>
<tr>
<td>RANK</td>
<td>0.136</td>
<td>0.12</td>
<td>1.18</td>
<td>0.25</td>
</tr>
<tr>
<td>AOA-US</td>
<td>0.001</td>
<td>0.01</td>
<td>0.07</td>
<td>0.94</td>
</tr>
<tr>
<td>USE-S</td>
<td>0.275</td>
<td>0.51</td>
<td>0.54</td>
<td>0.59</td>
</tr>
<tr>
<td>RANK:AOA-US</td>
<td>-0.001</td>
<td>0.01</td>
<td>-0.21</td>
<td>0.84</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>-0.307</td>
<td>0.28</td>
<td>-1.12</td>
<td>0.27</td>
</tr>
</tbody>
</table>

† p < .1    *p < .05     ** p < .01     ***p < .001

Model estimates for RC sentence segment 4 are shown below in Table 18. The segment 4 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for RANK and TRIAL. Except for the high correlation between the fixed effects of RANK and TRIAL (r = -.82), correlations between all fixed effects were less than ±0.4, indicating low collinearity among model fixed effects.

The segment 4 model for late bilinguals captured 58% of the variance in log RT ($R^2$ = .58) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2$ (10) = 25.89, $p < .01$). As in the segment 3 model, the coefficient estimate for TRIAL was also significant at segment 4 for late bilinguals ($\beta = -0.371$, $SE = 0.13$, $p = .01$). Unlike the segment 3 model, there were four significant effects involving language exposure and use predictors. The significant main effect of LOR-US ($\beta = 0.042$, $SE = 0.01$, $p < 0.01$) indicates that RTs were overall significantly longer for late bilinguals who had been exposed to English longer compared to late bilinguals who had been immersed in English for shorter periods. However, the significant interaction between RANK and LOR-US indicates that this difference is driven primarily by longer RTs at the beginning of the experiment for late bilinguals who had more exposure to English—by the end of the experiment, RTs were more similar regardless of length of exposure to English. As a result, repeated exposure to the RC sentences led to greater reductions in RT for these bilinguals over the course of the experiment compared to those who had been immersed in English for less time ($\beta = -0.022$, $SE = 0.01$, $p = 0.02$). The marginally significant main effect of USE-S also indicates that RTs were shorter for late bilinguals who used more Spanish in daily interactions ($\beta = -
1.147, \( SE = 0.60, p = 0.067 \). In contrast to the interaction between RANK and LOR-US, the interaction between RANK and USE-S indicates that RTs were similar at the start of the experiment regardless of differences in current Spanish use, and repeated exposure to the RC sentences led to greater reductions in RTs for late bilinguals who currently use more Spanish in daily interactions compared to late bilinguals who use less Spanish (\( \beta = -0.703, SE = 0.37, p = 0.07 \)). These two interactions are plotted below in Figure 2 and Figure 3.

Figure 2: Interaction between RANK and LOR-US on RC sentence log RTs for late bilinguals at PS sentence segment 4. Values for LOR-US represent the first quartile (-5.33), mean (0), and third quartile (2.67) of this variable for late bilinguals.
Figure 3: Interaction between RANK and USE-S on RC sentence log RTs for late bilinguals at PS sentence segment 4. Values for LOR-US represent the first quartile (-0.13), mean (0), and third quartile (0.07) of this variable for late bilinguals.

Table 18: RC sentence segment 4 linear mixed-effects model estimates for late bilinguals (n=21). The intercept represents the grand mean log RT at the mean value for each centered predictor.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>6.595</td>
<td>0.13</td>
<td>51.55</td>
<td>0.00***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.371</td>
<td>0.13</td>
<td>-2.88</td>
<td>0.01*</td>
</tr>
<tr>
<td>RANK</td>
<td>0.058</td>
<td>0.12</td>
<td>0.47</td>
<td>0.64</td>
</tr>
<tr>
<td>AGE-E</td>
<td>0.000</td>
<td>0.02</td>
<td>-0.02</td>
<td>0.98</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.042</td>
<td>0.01</td>
<td>3.16</td>
<td>0.00**</td>
</tr>
<tr>
<td>USE-S</td>
<td>-1.147</td>
<td>0.60</td>
<td>-1.93</td>
<td>0.07†</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>0.169</td>
<td>0.72</td>
<td>0.23</td>
<td>0.82</td>
</tr>
<tr>
<td>RANK:AGE-E</td>
<td>-0.019</td>
<td>0.01</td>
<td>-1.56</td>
<td>0.13</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.022</td>
<td>0.01</td>
<td>-2.57</td>
<td>0.02*</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>-0.703</td>
<td>0.37</td>
<td>-1.92</td>
<td>0.07†</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>-0.762</td>
<td>0.47</td>
<td>-1.64</td>
<td>0.12</td>
</tr>
</tbody>
</table>

† p < .1  *p < .05  ** p < .01  ***p < .001

Summary of Findings

The main objective of the baseline syntactic processing analysis was to determine whether heritage speakers and late bilinguals showed similar syntactic processing patterns for grammatical Spanish RC sentences. The summarized results of the by-group analysis are shown below in Table 19. The effect of TRIAL shows that RTs generally decreased for all subjects at both segments as the
experiment progressed, reflecting adaptation to the self-paced listening task. The lack of significance for the effect of GROUP at segment 3 (containing the RC verb and direct object (for donde items) or optional indirect object (for que items)) indicates that heritage speakers and late bilinguals RTs did not have significantly different RTs at this sentence segment. In contrast, the significant main effect of GROUP at segment 4 (the sentence final adjunct phrase modifying the RC VP) indicates that heritage speakers processed this sentence segment significantly faster than late bilinguals. A lack of significance for the main effect of RANK and the interaction of RANK and GROUP further suggests that repeated exposure to the RC sentences had no consistent effect among heritage speakers or late bilinguals at either sentence segment.

Table 19: Summary of fixed effects coefficients for the log RT group-level analysis at RC sentence segments 3 and 4.

<table>
<thead>
<tr>
<th>Fixed effect</th>
<th>Segment 3</th>
<th>Segment 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>6.067 ***</td>
<td>6.458 ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.120 *</td>
<td>-0.194 *</td>
</tr>
<tr>
<td>RANK</td>
<td>0.012</td>
<td>-0.051</td>
</tr>
<tr>
<td>GROUP(LB)</td>
<td>-0.040</td>
<td>0.308 †</td>
</tr>
<tr>
<td>RANK:GROUP(LB)</td>
<td>-0.016</td>
<td>-0.016</td>
</tr>
</tbody>
</table>

† p < .1   *p < .05   ** p < .01   ***p < .001

The results of the analyses conducted separately by group are summarized below in Table 20. These results show that among individuals in each group, there were some significant differences in syntactic processing related to age of English acquisition, length of immersion in an English-speaking environment, current use of Spanish, Spanish-English oral fluency ratio, and cumulative priming. Starting with the effect of TRIAL, these results show that for late bilinguals but not heritage speakers RTs significantly decreased at segment 3 and 4 over the course of the experiment. This finding indicates that the main effect of TRIAL in the by-group analysis was driven primarily by decreases in RT among late bilinguals. While this result does not bear directly on the research questions of the present study, it

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52 The predictor TRIAL is included in these and all models reported in this chapter in order to control for the effects of task adaptation on the results. Since this predictor serves only as a control and has no theoretical importance for the present study, no interaction terms were entered between TRIAL and any other predictors in these models. The lack of interaction terms involving TRIAL explains why the
suggests that the late bilinguals who were tested experienced greater effects of task adaptation than did the heritage speakers.

Turning to the main effects related to language experience, the main finding is that heritage speakers’ and late bilinguals’ syntactic processing was affected by different aspects of language experience, use, and proficiency. While differences in Spanish-English fluency among late bilinguals did not have a significant effect on processing at either segment, heritage speakers’ processing was influenced by Spanish-English fluency at segments 3 and 4—at both segments, processing was slower for heritage speakers who had higher fluency in Spanish compared to English. Likewise, while age of English acquisition did not influence syntactic processing among late bilinguals at either segment, processing was significantly faster at segment 4 (but not segment 3) for heritage speakers who were exposed to English later in childhood. In contrast, heritage speakers’ syntactic processing was not significantly influenced by differences in length of exposure to English or current use of Spanish in daily interactions, although both of these variables affected syntactic processing for late bilinguals. Among late bilinguals, longer immersion in English (LOR-US) corresponded to slower processing of segment 4 at the start of the experiment, but repeated exposure to the RC sentences reduced this difference over the course of the experiment. Processing at segment 4 was also influenced by the amount of current Spanish use (USE-S) for late bilinguals although this difference was primarily driven by greater decreases in RTs over the course of the experiment following repeated exposure to RC sentences for late bilinguals who currently use the most Spanish. These interactions suggest that certain late bilinguals (namely, those who currently use the most Spanish and those who have been exposed to English the longest) are sensitive to cumulative priming effects for the RC sentences, while the lack of any significant effects involving RANK for heritage speakers suggests that the individuals in this group do not experience facilitated processing of RC sentences following repeated exposure to them.

difference between heritage speakers and late bilinguals that surfaced in the separate analysis did not appear in the by-group analysis.
In addition to the results of the RT analysis, the analysis of comprehension question accuracy indicates that heritage speakers and late bilinguals had similarly high rates of comprehension for these sentences. Together, these findings show that overall, heritage speakers and late bilinguals processed grammatical Spanish RC sentences similarly, although late bilinguals spent longer processing the sentence final segments and there were processing differences within each group related to differences in language experience. For heritage speakers, differences in age of English acquisition and current Spanish-English fluency had a significant impact on real time syntactic processing of these sentences. While processing was faster for heritage speakers who were exposed to English later in childhood (and were therefore monolingual Spanish speakers for a longer period), processing was slower for heritage speakers who had higher fluency in Spanish than English at the time of testing. Importantly, differences in age of English acquisition and Spanish-English fluency did not affect syntactic processing for late bilinguals, although amount of English exposure and current use of Spanish did have an effect. Lastly, the largest effects of cumulative priming on increasing processing speed were found for late bilinguals who currently use more Spanish in daily interactions and those who have been exposed to English the longest, while heritage speakers did not show any indication of cumulative priming for these grammatical sentences.
CROSS-LINGUISTIC STRUCTURAL PRIMING RESULTS

To address RQ 1, the main experiment of the present study was designed to determine whether exposure to an a-priori English-specific structure could facilitate syntactic processing of a structurally identical (but ungrammatical) Spanish sentence among heritage speakers and late bilinguals. To address RQ 2, the results of the main experiment were analyzed with linear mixed-effects models that included predictor variables related to language exposure, use, and proficiency. The analyses and results of this experiment are reported below.

Data Preparation

As in the baseline syntactic processing analysis, RT was measured for each segment in the target Spanish PS sentences as the time between the offset of the recording for each segment and the moment the subject pressed the button on the SR Box to hear the next segment. Likewise, RTs were log transformed and trimmed following the procedure outlined above in the Data Preparation section of the baseline syntactic processing results. Outlier removal for PS sentences affected 5.29% of data points across subjects, segments, and conditions. The number of data points removed and corresponding percentage of total data points are shown across subjects by segment by condition in Table 21, below.

Table 21: Data points removed as a percentage of total data points across heritage speakers and late bilinguals by segment by condition.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Condition</th>
<th>Total Samples</th>
<th>Outliers</th>
<th>% Outliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prime</td>
<td>1449</td>
<td>102</td>
<td>7.04</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>1449</td>
<td>84</td>
<td>5.80</td>
</tr>
<tr>
<td>2</td>
<td>Prime</td>
<td>1449</td>
<td>69</td>
<td>4.76</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>1449</td>
<td>76</td>
<td>5.24</td>
</tr>
<tr>
<td>3</td>
<td>Prime</td>
<td>1449</td>
<td>94</td>
<td>6.49</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>1449</td>
<td>91</td>
<td>6.28</td>
</tr>
<tr>
<td>4</td>
<td>Prime</td>
<td>1449</td>
<td>54</td>
<td>3.73</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>1449</td>
<td>43</td>
<td>2.97</td>
</tr>
</tbody>
</table>

Results

As in the baseline syntactic processing analysis, the structural priming analysis reported below included only those 50 subjects (29 heritage speakers, 21 late bilinguals) who completed the oral fluency task. In the target Spanish PS sentences, RTs were analyzed at segment 3 because this is where the
filler-gap dependency involving the relativized prepositional object would be completed. RTs at segment 4 were also analyzed because syntactic processing difficulties often register downstream from where they occur (Papadopoulou et al., 2014). The principal effect under analysis here, structural priming, is indicated by a relative decrease in RTs for target Spanish PS sentences in prime trials compared to PS sentences in control trials.

**Heritage Speakers vs. Late Bilinguals**

Mean trimmed RTs for target PS sentences are shown in three figures below: Figure 4 shows mean RTs for PS sentences in the control condition by segment by group. Figure 5 shows mean RTs for PS sentences in the prime condition by segment by group. These two plots are overlaid in Figure 6 to show RTs by segment by group by condition (control vs. prime). The segmentation for target PS sentences plotted in Figure 4–Figure 6 is shown in Table 22 and the RT data corresponding to Figure 6 are shown for heritage speakers in Table 23 and for late bilinguals in Table 24, below.

![Figure 4: Mean RTs for PS sentences in the control condition by segment for heritage speakers and late bilinguals.](image)
Figure 5: Mean RTs for PS sentences in the prime condition by segment for heritage speakers and late bilinguals.

Figure 6: Mean RTs for PS sentences by condition by segment for heritage speakers and late bilinguals.
Table 22: Segmentation for target PS sentences.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Condition</th>
<th>Samples</th>
<th>Mean (ms)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control</td>
<td>631</td>
<td>459.54</td>
<td>386.67</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>629</td>
<td>465.68</td>
<td>437.53</td>
</tr>
<tr>
<td>2</td>
<td>Control</td>
<td>633</td>
<td>474.36</td>
<td>262.70</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>636</td>
<td>443.40</td>
<td>243.35</td>
</tr>
<tr>
<td>3</td>
<td>Control</td>
<td>626</td>
<td>517.64</td>
<td>520.65</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>635</td>
<td>533.28</td>
<td>600.18</td>
</tr>
<tr>
<td>4</td>
<td>Control</td>
<td>645</td>
<td>880.66</td>
<td>1039.72</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>641</td>
<td>775.86</td>
<td>1084.52</td>
</tr>
</tbody>
</table>

Figure 4 and Figure 5 (overlaid in Figure 6) show an overall similar pattern of RTs for heritage speakers and late bilinguals and a few points of divergence between the groups, most notably at segment 3 (the critical sentence region) and segment 4 (the spillover region). While mean RTs at segment 1 (e.g., *Esta es la tienda “this is the store”) and segment 2 (e.g., *que Gonzalo “that Gonzalo”) are generally very similar for the prime and control condition in both groups, late bilinguals show a faster mean RT in the prime condition compared to control condition at segment 3 containing the RC verb, direct object, and stranded preposition (e.g., *compró el pollo en “bought the chicken in”). Heritage speakers, on the other hand, show similar mean RTs between the prime and control conditions at segment 3, which are very similar to late bilinguals’ mean RT in the control condition. At segment 4, containing the adjunct phrase modifying the RC VP (e.g., *para cocinar la cena “to cook dinner”) both groups show faster mean RTs in the prime condition compared to the control condition. Between the groups, mean RTs at segment 4 in both conditions appear to be slower for late bilinguals compared to heritage speakers, with mean RT in the heritage speaker control condition nearly the same as late bilinguals’ mean RT in the prime condition.

Table 23: Mean raw RTs for heritage speakers by segment by condition (outliers removed).

<table>
<thead>
<tr>
<th>Segment</th>
<th>Condition</th>
<th>Samples</th>
<th>Mean (ms)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control</td>
<td>631</td>
<td>459.54</td>
<td>386.67</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>629</td>
<td>465.68</td>
<td>437.53</td>
</tr>
<tr>
<td>2</td>
<td>Control</td>
<td>633</td>
<td>474.36</td>
<td>262.70</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>636</td>
<td>443.40</td>
<td>243.35</td>
</tr>
<tr>
<td>3</td>
<td>Control</td>
<td>626</td>
<td>517.64</td>
<td>520.65</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>635</td>
<td>533.28</td>
<td>600.18</td>
</tr>
<tr>
<td>4</td>
<td>Control</td>
<td>645</td>
<td>880.66</td>
<td>1039.72</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>641</td>
<td>775.86</td>
<td>1084.52</td>
</tr>
</tbody>
</table>
Table 24: Mean raw RTs for late bilinguals by segment by condition (outliers removed).

<table>
<thead>
<tr>
<th>Segment</th>
<th>Condition</th>
<th>Samples</th>
<th>Mean (ms)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control</td>
<td>449</td>
<td>446.51</td>
<td>303.12</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>445</td>
<td>423.30</td>
<td>266.00</td>
</tr>
<tr>
<td>2</td>
<td>Control</td>
<td>457</td>
<td>491.90</td>
<td>408.70</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>462</td>
<td>478.76</td>
<td>299.81</td>
</tr>
<tr>
<td>3</td>
<td>Control</td>
<td>452</td>
<td>515.37</td>
<td>460.01</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>444</td>
<td>439.07</td>
<td>358.14</td>
</tr>
<tr>
<td>4</td>
<td>Control</td>
<td>475</td>
<td>952.45</td>
<td>979.12</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>468</td>
<td>883.07</td>
<td>924.83</td>
</tr>
</tbody>
</table>

Separate linear mixed-effects models were generated for segments 3 and 4 to test the effects of condition (prime vs. control) and group (late bilingual vs. heritage speaker) on the dependent variable, log-transformed RT. The mixed-effects model for each segment contained the following fixed effects: log-transformed trial number (TRIAL), condition (COND), group (GROUP), trial rank (RANK), and the interactions between COND, GROUP, and RANK. These variables were selected based on theoretical considerations: faster responses in the dependent variable (log RT) are taken as an indication of facilitated processing (Mitchell, 2004); COND is included to test the hypothesis that exposure to preposition stranding in the English prime sentence will result in faster processing of preposition stranding in the Spanish PS sentence within the same trial; GROUP is included to test whether heritage speakers show differences in processing Spanish PS sentences compared to late bilinguals; and RANK is included to test the effects of repeated exposure to the Spanish PS sentences on cumulative priming over the course of the experiment. The interaction of GROUP and COND was included to determine whether there were differences in within-trial priming effects between groups. The interaction of GROUP and RANK was included to determine whether there were differences in cumulative priming effects between groups. The interaction of RANK and COND was included to determine whether the within-trial priming effect changed with repeated exposure to the PS sentences. The three-way interaction between GROUP, COND, and RANK was included to determine whether any changes in within-trial priming effects following repeated exposure to PS sentences were the same or different between groups. TRIAL was included to control for
changes in RT over the course of the experiment due to task adaptation (Baayen, 2008). For all model estimates, predictor significance was tested with the lmerTest package (Kuznetsova et al., 2017) in R with maximum likelihood t-tests using Satterthwaite approximations for degrees of freedom. The inclusion of the predictor variables in each model was justified using likelihood ratio tests to compare the goodness of fit to a model containing only the random effects structure (Baayen, 2008).

The predictor variables COND and GROUP were contrast coded (aka sum coded) for the segment 3 and segment 4 models to reduce collinearity between fixed effects involving these predictors. As in the baseline syntactic processing analysis, the predictor variables TRIAL and RANK were mean centered to avoid collinearity with the model intercept (Baayen, 2008). With this coding scheme, the coefficient for the model intercept represents the GRAND MEAN log RT at the mean trial number and mean rank number. For each contrast-coded predictor, the coefficient represents the difference in mean log-transformed RT between the comparison level for that predictor (indicated in parentheses) and the grand mean log RT at the mean trial number and mean rank number.

Segment 3 mean log RTs are plotted by group by condition below in Figure 7 and the corresponding model estimates are shown below in Table 25. The segment 3 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge (Barr et al., 2013): random intercepts for subjects and items, as well as by-subject and by-item random slopes for COND, RANK, TRIAL, and the interaction between COND and RANK. Except for the high correlation between the fixed effects of RANK and TRIAL ($r = -.86$), correlations between all fixed effects were less than ±0.26, indicating low collinearity among model fixed effects.

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53 As mentioned earlier, Fine and Jaeger (2013) motivate the distinction between trial order and trial rank and justify the inclusion of both predictors in structural priming experiments. It should be noted that in the present analysis, two sets of models were generated: one set including both RANK and TRIAL as fixed effects and the other set including only un-transformed TRIAL. The coefficients for fixed effects involving GROUP and COND between these sets of models were qualitatively identical, which indicates that the inclusion of both RANK and TRIAL does not generate any spurious results compared to the inclusion of TRIAL only. Differences in fixed effects coefficients between these model sets occur only in the unique contributions of RANK versus TRIAL.

54 An initial set of PS sentence models constructed with treatment coding for the COND and GROUP revealed high correlations ($r > .7$) between several fixed effects and interactions. For this reason, the COND and GROUP variables were recoded with contrast coding which resulted in low correlations between the intercept and all fixed effects and interactions for all models (except for the fixed effects of RANK and TRIAL, which were highly correlated in each model reported below). Fixed effects correlations are reported separately for each model below.
Figure 7: Mean log RTs at target PS sentence segment 3 plotted by group by condition. Error bars represent 95% confidence intervals.

Table 25: Target segment 3 linear mixed-effects model estimates for heritage speakers and late bilinguals. The intercept represents grand mean log RT at the mean trial number and mean rank number.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>5.941</td>
<td>0.07</td>
<td>89.85</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.075</td>
<td>0.03</td>
<td>-2.25</td>
<td>0.03</td>
</tr>
<tr>
<td>RANK</td>
<td>-0.038</td>
<td>0.04</td>
<td>-0.99</td>
<td>0.33</td>
</tr>
<tr>
<td>COND(PRIME)</td>
<td>-0.035</td>
<td>0.03</td>
<td>-1.23</td>
<td>0.23</td>
</tr>
<tr>
<td>GROUP(LB)</td>
<td>-0.060</td>
<td>0.13</td>
<td>-0.46</td>
<td>0.65</td>
</tr>
<tr>
<td>RANK:COND(PRIME)</td>
<td>-0.014</td>
<td>0.02</td>
<td>-0.57</td>
<td>0.57</td>
</tr>
<tr>
<td>RANK:GROUP(LB)</td>
<td>0.025</td>
<td>0.04</td>
<td>0.66</td>
<td>0.52</td>
</tr>
<tr>
<td>COND(PRIME):GROUP(LB)</td>
<td>-0.118</td>
<td>0.05</td>
<td>-2.24</td>
<td>0.03</td>
</tr>
<tr>
<td>RANK:COND(PRIME):GROUP(LB)</td>
<td>0.046</td>
<td>0.05</td>
<td>0.98</td>
<td>0.33</td>
</tr>
</tbody>
</table>

* p < .05  ** p < .01  *** p < .001

The segment 3 model captured 54% of the variance in log RT ($R^2 = .54$) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (8) = 39.01, p < .001$). The coefficient estimate for TRIAL indicates a significant effect of trial number on log RT at segment 3 ($\beta = -0.075, SE = 0.03, p = .03$): For each unit increase in trial number, log RT decreased, indicating overall faster response times at segment 3 as the experiment progressed. The estimate for COND indicates faster response times
in the prime condition compared to the grand mean log RT, although this effect did not reach significance ($\beta = -0.035, \ SE = 0.03, \ p = 0.23$). Likewise, the estimate for GROUP indicates faster response times for late bilinguals compared to the grand mean log RT, although this effect did not reach significance ($\beta = -0.060, \ SE = 0.13, \ p = 0.65$). There was, however, a significant interaction between COND and GROUP, which indicates that in the prime condition, late bilinguals responded significantly faster than the grand mean log RT ($\beta = -0.118, \ SE = 0.05, \ p = 0.03$). This interaction suggests a within-trial priming effect at segment 3 for late bilinguals but not for heritage speakers. The lack of significant interactions between RANK and COND, RANK and GROUP, and the three-way interaction between RANK, COND, and GROUP also suggests that the within-trial priming effect observed for late bilinguals at segment 3 did not significantly change following repeated exposure to PS sentences.

Segment 4 log RTs are plotted by group by condition below in Figure 8 and the corresponding model estimates are shown below in Table 26. The segment 4 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for COND, RANK, TRAIL, and the interaction between COND and RANK. Except for the high correlation between the fixed effects of RANK and TRAIL ($r = -0.88$), correlations between all other fixed effects and their interactions were less than $\pm 0.27$, indicating low collinearity.
Figure 8: Mean log RTs at target PS sentence segment 4 plotted by group by condition. Error bars represent 95% confidence intervals.

Table 26: Target segment 4 linear mixed-effects model estimates for heritage speakers and late bilinguals. The intercept represents the grand mean log RT at the mean trial number and mean rank number.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>6.263</td>
<td>0.09</td>
<td>69.62</td>
<td>&lt;.001   ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.268</td>
<td>0.06</td>
<td>-4.58</td>
<td>&lt;.001   ***</td>
</tr>
<tr>
<td>RANK</td>
<td>0.067</td>
<td>0.07</td>
<td>1.02</td>
<td>0.31</td>
</tr>
<tr>
<td>COND(PRIME)</td>
<td>-0.067</td>
<td>0.05</td>
<td>-1.42</td>
<td>0.16</td>
</tr>
<tr>
<td>GROUP(LB)</td>
<td>0.133</td>
<td>0.18</td>
<td>0.76</td>
<td>0.45</td>
</tr>
<tr>
<td>RANK:COND(PRIME)</td>
<td>-0.065</td>
<td>0.05</td>
<td>-1.40</td>
<td>0.17</td>
</tr>
<tr>
<td>RANK:GROUP(LB)</td>
<td>0.046</td>
<td>0.06</td>
<td>0.79</td>
<td>0.44</td>
</tr>
<tr>
<td>COND(PRIME):GROUP(LB)</td>
<td>0.035</td>
<td>0.09</td>
<td>0.39</td>
<td>0.70</td>
</tr>
<tr>
<td>RANK:COND(PRIME):GROUP(LB)</td>
<td>-0.022</td>
<td>0.09</td>
<td>-0.25</td>
<td>0.80</td>
</tr>
</tbody>
</table>

† $p < .1$  * $p < .05$  ** $p < .01$  *** $p < .001$

The segment 4 model captured 47% of the variance in log RT ($R^2 = .47$) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (8) = 52.05, p < .001$). The coefficient estimate for TRIAL indicates a significant effect of trial number on log RT at segment 4 ($\beta = -0.268$, $SE = 0.06, p < .001$): For each unit increase in trial number, log RT decreased, indicating overall faster response times at segment 4 as the experiment progressed. The estimate for COND indicates faster
response times in the prime condition compared to the grand mean log RT, although this effect did not reach significance ($\beta = -0.067$, $SE = 0.05$, $p = 0.16$). Likewise, the estimate for GROUP indicates slower response times for late bilinguals compared to the grand mean log RT, although this effect did not reach significance ($\beta = 0.133$, $SE = 0.18$, $p = 0.45$). Unlike segment 3, there was no significant interaction between COND and GROUP. Although the coefficient estimate for the interaction between condition and group suggests that the effect of within-trial structural priming on log RT was reduced for late bilinguals compared to heritage speakers (reflected in Figure 8 as a smaller difference in mean log RT between prime and control conditions for late bilinguals compared to heritage speakers) this difference did not reach significance ($\beta = 0.035$, $SE = 0.09$, $p = 0.7$). The lack of significant interactions between RANK and COND, RANK and GROUP, and the three-way interaction between RANK, COND, and GROUP also suggests that repeated exposure to PS sentences had no consistent cumulative priming effect for either group or condition.

**Language Exposure, Use, and Proficiency**

To address RQ 2, heritage speakers and late bilinguals were analyzed separately to determine whether individual differences in language exposure, use, and proficiency within each group modulated the effects of within-trial or cumulative structural priming for Spanish PS sentence segments 3 and 4. Since the priming analysis included the same 50 subjects that were included in the baseline syntactic processing analysis, the predictor variables for heritage speakers and late bilinguals were the same as those included in the baseline syntactic processing analysis reported above.

**Heritage Speakers**

As in the by-group analysis, PS sentence segments 3 and 4 were analyzed in two separate linear mixed-effects models. In each model, each of the predictors related to language experience was mean centered to reduce collinearity: AGE-E, LOR-US, USE-S, FLU-SE. The model for each segment also contained the same predictors that were included in the by-group analysis reported above (excluding GROUP): log-transformed trial number (TRIAL), condition (COND), trial rank (RANK), the interaction between COND and RANK. As in the by-group analysis reported above, the predictor variable COND was contrast coded (aka sum coded) for the segment 3 and segment 4 models to reduce collinearity between the fixed effects, and
the predictor variables RANK and TRIAL were also mean centered to avoid collinearity with the model intercept. With this coding scheme, the segment 3 and segment 4 model intercepts represent the GRAND MEAN log RT at the mean value for each centered predictor: RANK, TRIAL, AGE-E, LOR-US, USE-S, and FLUSE. For the contrast-coded predictor COND, the coefficient represents the difference in log RT between the prime condition (PRIME) and the grand mean log RT. For each centered predictor, the coefficient represents the change in log RT for each unit increase in the predictor. As in the by-group analysis reported above, the dependent variable for each model was log RT.

Model estimates for PS sentence segment 3 are shown below in Table 27. The segment 3 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for COND, RANK, TRIAL, and the interaction between COND and RANK. Except for the high correlation between the fixed effects of RANK and TRIAL ($r = -.86$), correlations between all fixed effects were less than ±0.4, indicating low collinearity among model fixed effects.

The segment 3 model for heritage speakers captured 60% of the variance in log RT ($R^2 = .60$) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (20) = 32.18, p = .04$). As in the by-group analysis, the coefficient estimate for TRIAL indicates a marginally significant effect of task adaptation at segment 3 for heritage speakers: For each unit increase in log trial number, log RT decreased ($\beta = -0.084, SE = 0.04, p = .051$), indicating overall faster response times at PS sentence segment 3 as the experiment progressed. As expected, given the segment 3 model estimates in the by-group analysis, the estimate for COND suggests that segment 3 RTs were not significantly different in the prime condition compared to the grand mean RT ($\beta = 0.024, SE = 0.03, p = 0.47$). However, there were marginally significant main effects for two predictor variables related to language exposure and proficiency. While the non-significant estimate for AGE-E ($\beta = -0.014, SE = 0.04, p = 0.72$) suggests that overall response times at PS sentence segment 3 were not influenced by the age at which heritage speakers were exposed to English, the estimate for LOR-US was marginally significant ($\beta = 0.035, SE = 0.02, p = 0.078$). This indicates that overall response times at segment 3 were longer for heritage speakers who have been exposed to English for longer periods and this effect is independent from variation in response times related to age of English acquisition due to the residualization of LOR-US onto
The marginally significant estimate for FLU-SE ($\beta = 1.337$, $SE = 0.66$, $p = 0.051$) indicates an increase in log RT with each unit increase in Spanish-English fluency ratio. The lack of any interactions involving these predictors suggests that independent of when a PS sentence was encountered in the experiment or whether it was in a prime or control trial, RTs at segment 3 were significantly longer for heritage speakers who had higher fluency in Spanish than English compared to heritage speakers who had higher fluency in English than Spanish and RTs significantly increased for heritage speakers with increases in length of exposure to English.

Table 27: PS sentence segment 3 model estimates for heritage speakers (n=29). The intercept represents the grand mean log RT at the mean value for each centered predictor.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>5.968</td>
<td>0.08</td>
<td>72.38</td>
<td>&lt;.001   ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.084</td>
<td>0.04</td>
<td>-1.98</td>
<td>0.051   †</td>
</tr>
<tr>
<td>RANK</td>
<td>-0.044</td>
<td>0.05</td>
<td>-0.87</td>
<td>0.39</td>
</tr>
<tr>
<td>COND(PRIME)</td>
<td>0.024</td>
<td>0.03</td>
<td>0.73</td>
<td>0.47</td>
</tr>
<tr>
<td>AGE-E</td>
<td>-0.014</td>
<td>0.04</td>
<td>-0.36</td>
<td>0.72</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.035</td>
<td>0.02</td>
<td>1.83</td>
<td>0.078   †</td>
</tr>
<tr>
<td>USE-S</td>
<td>-0.027</td>
<td>0.06</td>
<td>-0.04</td>
<td>0.97</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>1.337</td>
<td>0.66</td>
<td>2.03</td>
<td>0.051   †</td>
</tr>
<tr>
<td>RANK:COND(PRIME)</td>
<td>-0.036</td>
<td>0.03</td>
<td>-1.27</td>
<td>0.21</td>
</tr>
<tr>
<td>RANK:AGE-E</td>
<td>0.000</td>
<td>0.01</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.004</td>
<td>0.01</td>
<td>-0.72</td>
<td>0.48</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>0.043</td>
<td>0.19</td>
<td>0.22</td>
<td>0.83</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>0.078</td>
<td>0.21</td>
<td>0.38</td>
<td>0.71</td>
</tr>
<tr>
<td>COND(PRIME):AGE-E</td>
<td>0.024</td>
<td>0.01</td>
<td>1.69</td>
<td>0.10</td>
</tr>
<tr>
<td>COND(PRIME):LOR-US</td>
<td>-0.003</td>
<td>0.01</td>
<td>-0.38</td>
<td>0.71</td>
</tr>
<tr>
<td>COND(PRIME):USE-S</td>
<td>-0.051</td>
<td>0.24</td>
<td>-0.22</td>
<td>0.83</td>
</tr>
<tr>
<td>COND(PRIME):FLU-SE</td>
<td>-0.156</td>
<td>0.25</td>
<td>-0.62</td>
<td>0.54</td>
</tr>
<tr>
<td>RANK:COND(PRIME):AGE-E</td>
<td>0.010</td>
<td>0.01</td>
<td>0.73</td>
<td>0.47</td>
</tr>
<tr>
<td>RANK:COND(PRIME):LOR-US</td>
<td>0.000</td>
<td>0.01</td>
<td>0.02</td>
<td>0.98</td>
</tr>
<tr>
<td>RANK:COND(PRIME):USE-S</td>
<td>-0.058</td>
<td>0.22</td>
<td>-0.27</td>
<td>0.79</td>
</tr>
<tr>
<td>RANK:COND(PRIME):FLU-SE</td>
<td>-0.261</td>
<td>0.23</td>
<td>-1.11</td>
<td>0.27</td>
</tr>
</tbody>
</table>

† $p < .1$  *$p < .05$  **$p < .01$  ***$p < .001$

Model estimates for segment 4 are shown below in Table 28. The segment 4 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for COND, RANK, TRIAL, and the interaction between COND and RANK. Except for the high correlation
between the fixed effects of RANK and TRIAL ($r = -.92$), correlations between all fixed effects were less than ±0.4, indicating low collinearity among model fixed effects.

The segment 4 model for heritage speakers captured 56% of the variance in log RT ($R^2 = .56$) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (20) = 52.45, p < .001$). As in the by-group analysis, the coefficient estimate for TRIAL indicates a significant effect of trial number on log RT at segment 4 for heritage speakers ($\beta = -0.221, SE = 0.08, p = .012$): For each unit increase in trial number, log RT decreased, indicating overall faster response times at PS sentence segment 4 as the experiment progressed. As expected, given the segment 4 model estimates in the by-group analysis, the coefficient for COND indicates faster response times in the prime condition compared to the grand mean log RT, although this effect does not reach significance ($\beta = -0.081, SE = 0.06, p = 0.16$). While the main effect of COND was not significant, there were two significant interactions involving COND. The interaction between COND and FLU-SE indicates that compared to heritage speakers’ grand mean log RT at segment 4, log RTs in the prime condition decreased significantly with each unit increase in Spanish-English fluency ratio ($\beta = -1.018, SE = 0.45, p = 0.03$). This means that heritage speakers who were more fluent in Spanish than English showed a greater effect of within-trial priming at PS sentence segment 4 compared to heritage speakers who were more fluent in English than Spanish. This interaction is plotted below in Figure 9.
The marginally significant interaction between RANK and AGE-E indicates that while heritage speakers who were exposed to English during later childhood showed faster RTs at the beginning of the experiment, repeated exposure to PS sentences led to significant overall increases in RTs for these same individuals ($\beta = 0.025$, $SE = 0.01$, $p = 0.099$). However, the significant three-way interaction between RANK, COND, and AGE-E indicates that the increase in RT for heritage speakers exposed to English later in childhood due to repeated exposure to PS sentences was driven primarily by changes in RTs for PS sentences in the control condition ($\beta = -0.056$, $SE = 0.03$, $p = 0.03$). While repeated exposure to the PS sentences (RANK) had a similar effect on reducing RTs for segment 4 in the prime condition across the range of ages of exposure to English (AGE-E), in the control condition, RTs increased with repeated exposure to PS sentences for heritage speakers who were exposed to English in later childhood. The interaction between RANK and AGE-E is plotted below in Figure 10 and the three-way interaction between RANK, AGE, and COND is plotted below in Figure 11.
Figure 10: Interaction between RANK and AGE-E on log RTs for heritage speakers at PS sentence segment 4. Values for AGE-E represent the first quartile (-0.86), mean (0), and third quartile (1.13) of this variable.

Figure 11: Interaction between COND, RANK, and AGE-E for heritage speakers at PS sentence segment 4. Values for AGE-E represent the first quartile (-0.86), mean (0), and third quartile (1.13) for this variable.
Table 28: Segment 4 linear mixed-effects model estimates for heritage speakers \( (n=29) \). The intercept represents the grand mean log RT at the mean value for each centered predictor.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>6.206</td>
<td>0.12</td>
<td>52.91</td>
<td>&lt;.001   ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.221</td>
<td>0.08</td>
<td>-2.67</td>
<td>0.01*</td>
</tr>
<tr>
<td>RANK</td>
<td>0.002</td>
<td>0.08</td>
<td>0.02</td>
<td>0.98</td>
</tr>
<tr>
<td>COND(PRIME)</td>
<td>-0.081</td>
<td>0.06</td>
<td>-1.43</td>
<td>0.16</td>
</tr>
<tr>
<td>AGE-E</td>
<td>-0.082</td>
<td>0.06</td>
<td>-1.49</td>
<td>0.15</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.018</td>
<td>0.03</td>
<td>0.65</td>
<td>0.52</td>
</tr>
<tr>
<td>USE-S</td>
<td>0.141</td>
<td>0.90</td>
<td>0.16</td>
<td>0.88</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>0.991</td>
<td>0.96</td>
<td>1.03</td>
<td>0.31</td>
</tr>
<tr>
<td>RANK:COND(PRIME)</td>
<td>-0.060</td>
<td>0.06</td>
<td>-1.04</td>
<td>0.30</td>
</tr>
<tr>
<td>RANK:AGE-E</td>
<td>0.025</td>
<td>0.01</td>
<td>1.70</td>
<td>0.099†</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.008</td>
<td>0.01</td>
<td>-1.03</td>
<td>0.31</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>0.047</td>
<td>0.24</td>
<td>0.19</td>
<td>0.85</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>-0.088</td>
<td>0.26</td>
<td>-0.34</td>
<td>0.73</td>
</tr>
<tr>
<td>COND(PRIME):AGE-E</td>
<td>0.008</td>
<td>0.03</td>
<td>0.32</td>
<td>0.75</td>
</tr>
<tr>
<td>COND(PRIME):LOR-US</td>
<td>-0.010</td>
<td>0.01</td>
<td>-0.75</td>
<td>0.46</td>
</tr>
<tr>
<td>COND(PRIME):USE-S</td>
<td>-0.563</td>
<td>0.42</td>
<td>-1.34</td>
<td>0.19</td>
</tr>
<tr>
<td>COND(PRIME):FLU-SE</td>
<td>-1.018</td>
<td>0.45</td>
<td>-2.28</td>
<td>0.03*</td>
</tr>
<tr>
<td>RANK:COND(PRIME):AGE-E</td>
<td>-0.056</td>
<td>0.03</td>
<td>-2.20</td>
<td>0.03*</td>
</tr>
<tr>
<td>RANK:COND(PRIME):LOR-US</td>
<td>-0.012</td>
<td>0.01</td>
<td>-0.94</td>
<td>0.35</td>
</tr>
<tr>
<td>RANK:COND(PRIME):USE-S</td>
<td>0.151</td>
<td>0.42</td>
<td>0.36</td>
<td>0.72</td>
</tr>
<tr>
<td>RANK:COND(PRIME):FLU-SE</td>
<td>0.330</td>
<td>0.44</td>
<td>0.75</td>
<td>0.46</td>
</tr>
</tbody>
</table>

† \( p < .1 \)  * \( p < .05 \)  ** \( p < .01 \)  *** \( p < .001 \)

Late Bilinguals

Following the same procedure outlined in the heritage speaker analysis, two mixed-effects models were created to analyze the effects of differences in language exposure, use, and proficiency on late bilinguals' RTs for PS sentence segments 3 and 4. In each model, each of the predictors related to language experience was mean centered to reduce collinearity: AOA-US, LOR-US, USE-S, FLU-SE. The model for each segment also contained the same predictors that were included in the by-group analysis (excluding GROUP): log-transformed trial number (TRIAL), condition (COND), trial rank (RANK), the interaction between COND and RANK. The predictor variable COND was contrast coded (aka sum coded) for the segment 3 and segment 4 models to reduce collinearity between the fixed effects, and the predictor variables RANK and TRIAL were also mean centered to avoid collinearity with the model intercept. With this coding scheme, the coefficient for the model intercept represents the grand mean log RT at the mean value for each centered predictor. For the contrast-coded predictor COND, the coefficient represents the
difference in mean log-transformed RT between the prime condition (PRIME) and the grand mean log RT at the mean value for each centered predictor. For each centered predictor, the coefficient estimate represents the change in log-transformed RT for each unit increase in the predictor.

Model estimates for PS sentence segment 3 are shown below in Table 29. The segment 3 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject random slopes for COND, RANK, TRIAL, and the interaction between COND and RANK, and by-item random slopes for COND and RANK and the interaction between COND and RANK. Similar to the RC sentence segment 3 model for late bilinguals, the likelihood ratio test for the PS sentence segment 3 model for late bilinguals indicated that inclusion of the all fixed effects (TRIAL, RANK, AOA-US, LOR-US, USE-S, FLU-SE) did not improve the fit of this model over the null model that included only random effects ($\chi^2(20) = 28.04, p = .11$). To address this lack of significance, fixed effects were systematically removed and each resulting model was compared to the null model. This process resulted in a final model that excluded USE-S and contained only the fixed effects of TRIAL, RANK, AOA-US, LOR-US, and FLU-SE, which captured 45% of the variance in log RT ($R^2 = .45$) and was a marginally significant improvement over the fit of the null model ($\chi^2(16) = 25.39, p = .06$).55 Except for the expected high correlation between the fixed effects of RANK and TRIAL ($r = -.89$), correlations between all fixed effects were less than ±0.4, indicating low collinearity among model fixed effects.

Unlike in the by-group and heritage speaker analyses, the coefficient estimate for TRIAL was not significant at segment 3 for late bilinguals, suggesting a lack of significant changes in log RT over the course of the experiment ($\beta = -0.059, SE = 0.05, p = .27$). As expected, given the segment 3 model estimates in the by-group analysis, the estimate for COND was significant ($\beta = -0.095, SE = 0.04, p = 0.04$) indicating significantly shorter log RTs at PS sentence segment 3 in the prime condition compared to the grand mean log RT. In addition, there was a significant interaction between RANK and AOA-US ($\beta = -0.010, SE = 0.004, p = 0.03$) which indicates that with repeated exposure to PS sentences, segment 3 log RTs

55 In comparison to the reduced model, the full model containing all fixed effects produced fixed-effects coefficients that were qualitatively identical.
decreased more for late bilinguals who arrived to the U.S. later in adulthood compared to late bilinguals who arrived earlier in adulthood. This interaction is plotted below in Figure 12.

![Figure 12: Interaction between RANK and AOA-US for late bilinguals at PS sentence segment 3. The AOA-US values represent the first quartile (-4.57), mean (0), and third quartile (5.43) for late bilinguals for this variable.]

The marginally significant interaction between RANK and FLU-SE ($\beta = -0.296$, $SE = 0.17$, $p = 0.096$) also indicates that with repeated exposure to PS sentences, the decrease in log RT was significantly greater for late bilinguals who had relatively higher oral fluency in Spanish compared to English than for late bilinguals whose Spanish and English oral fluency rates were more similar. This interaction is plotted below in Figure 13.
Figure 13: Interaction between RANK and FLU-SE for late bilinguals at PS sentence segment 3. The FLU-SE values represent the first quartile (-0.12), mean (0), and third quartile (0.07) of this variable for late bilinguals.

Table 29: Segment 3 model estimates for late bilinguals (n=21). The intercept represents the grand mean log RT at the mean value for each centered predictor.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>5.914</td>
<td>0.08</td>
<td>71.56</td>
<td>&lt;.001 ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.059</td>
<td>0.05</td>
<td>-1.11</td>
<td>0.27</td>
</tr>
<tr>
<td>RANK</td>
<td>-0.035</td>
<td>0.06</td>
<td>-0.62</td>
<td>0.54</td>
</tr>
<tr>
<td>COND(PRIME)</td>
<td>-0.095</td>
<td>0.04</td>
<td>-2.16</td>
<td>0.04 *</td>
</tr>
<tr>
<td>AOA-US</td>
<td>-0.020</td>
<td>0.01</td>
<td>-1.32</td>
<td>0.20</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.008</td>
<td>0.01</td>
<td>0.71</td>
<td>0.49</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>-0.694</td>
<td>0.61</td>
<td>-1.15</td>
<td>0.26</td>
</tr>
<tr>
<td>RANK:COND(PRIME)</td>
<td>0.003</td>
<td>0.04</td>
<td>0.09</td>
<td>0.93</td>
</tr>
<tr>
<td>RANK:AOA-US</td>
<td>-0.010</td>
<td>0.00</td>
<td>-2.34</td>
<td>0.03 *</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.004</td>
<td>0.00</td>
<td>-1.25</td>
<td>0.22</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>-0.296</td>
<td>0.17</td>
<td>-1.74</td>
<td>0.096 †</td>
</tr>
<tr>
<td>COND(PRIME):AOA-US</td>
<td>0.005</td>
<td>0.01</td>
<td>0.66</td>
<td>0.52</td>
</tr>
<tr>
<td>COND(PRIME):LOR-US</td>
<td>0.000</td>
<td>0.01</td>
<td>0.05</td>
<td>0.96</td>
</tr>
<tr>
<td>COND(PRIME):FLU-SE</td>
<td>0.102</td>
<td>0.33</td>
<td>0.31</td>
<td>0.76</td>
</tr>
<tr>
<td>RANK:COND(PRIME):AOA-US</td>
<td>0.007</td>
<td>0.01</td>
<td>0.96</td>
<td>0.34</td>
</tr>
<tr>
<td>RANK:COND(PRIME):LOR-US</td>
<td>0.005</td>
<td>0.01</td>
<td>0.97</td>
<td>0.34</td>
</tr>
<tr>
<td>RANK:COND(PRIME):FLU-SE</td>
<td>0.238</td>
<td>0.29</td>
<td>0.83</td>
<td>0.41</td>
</tr>
</tbody>
</table>

† p < .1  *p < .05  ** p < .01  ***p < .001
Model estimates for segment 4 are shown below in Table 30. The segment 4 model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for COND, RANK, and TRIAL and the interaction between COND and RANK.\textsuperscript{56} Except for the expected high correlation between the fixed effects of RANK and TRIAL ($r = -.89$), correlations between all fixed effects were less than ±0.4, indicating low collinearity among model fixed effects.

The segment 4 model for late bilinguals captured 40\% of the variance in log RT ($R^2 = .40$) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (20) = 36.90, p = .01$). As in the by-group analysis, the coefficient estimate for TRIAL indicates a significant effect of trial number on log RT at segment 4 for late bilinguals: For each unit increase in trial number, log RT decreased ($\beta = -0.341$, $SE = 0.10, p < .001$), indicating overall faster response times at PS sentence segment 4 as the experiment progressed. Beyond this effect of task adaptation, the significant interaction between RANK and USE-S ($\beta = -0.617$, $SE = 0.26$, $p = .03$) indicates that although segment 4 RTs generally increased with repeated exposure to PS sentences, this increase was reduced for late bilinguals who currently use more Spanish in daily interactions, compared to late bilinguals who use less Spanish in daily interactions. This interaction is plotted below in Figure 14.

The significant three-way interaction between RANK, COND, and AOA-US ($\beta = 0.025$, $SE = 0.01$, $p = .04$) indicates that although segment 4 RTs generally increased with repeated exposure to the PS sentences, this increase was mitigated in the prime condition for late bilinguals who arrived to the U.S. earlier in adulthood, compared to those who arrived later. This interaction is plotted below in Figure 15.

The marginally significant interaction between RANK, COND, and LOR-US ($\beta = 0.017$, $SE = 0.01$, $p = .058$) also indicates that the general increase in segment 4 RTs following repeated exposure to PS sentences was mitigated in the prime condition for late bilinguals who had less exposure to English, compared to those who had been exposed to English for longer. This interaction is plotted below in Figure 16.

\textsuperscript{56} The by-item random correlations parameter was omitted from the segment 4 model for late bilinguals as the full model including by-item random correlations failed to converge.
Figure 14: Interaction between RANK and USE-S for late bilinguals at PS sentence segment 4. Values for USE-S represent the first quartile (-0.13), mean (0), and third quartile (0.07) of this variable for late bilinguals.

Figure 15: Interaction between RANK, COND, and AOA-US for late bilinguals at PS sentence segment 4. Values for AOA-US represent the first quartile (-4.57), mean (0), and third quartile (5.43) of this variable for late bilinguals.
Figure 16: Interaction between RANK, COND, and LOR-US for late bilinguals at PS sentence segment 4. Values for LOR-US represent the first quartile (-5.33), mean (0), and third quartile (2.67) of this variable.

Table 30: Segment 4 linear mixed-effects model estimates for late bilinguals (n=21). The intercept represents the grand mean log RT at the mean value for each centered predictor.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>6.316</td>
<td>0.12</td>
<td>53.07</td>
<td>&lt;.001 **</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.341</td>
<td>0.10</td>
<td>-3.55</td>
<td>&lt;.001 ***</td>
</tr>
<tr>
<td>RANK</td>
<td>0.163</td>
<td>0.11</td>
<td>1.50</td>
<td>0.14</td>
</tr>
<tr>
<td>COND(PRIME)</td>
<td>-0.063</td>
<td>0.07</td>
<td>-0.89</td>
<td>0.38</td>
</tr>
<tr>
<td>AOA-US</td>
<td>0.012</td>
<td>0.02</td>
<td>0.59</td>
<td>0.57</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.020</td>
<td>0.02</td>
<td>1.26</td>
<td>0.22</td>
</tr>
<tr>
<td>USE-S</td>
<td>-0.591</td>
<td>0.64</td>
<td>-0.92</td>
<td>0.37</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>0.167</td>
<td>0.83</td>
<td>0.20</td>
<td>0.84</td>
</tr>
<tr>
<td>RANK:COND(PRIME)</td>
<td>-0.067</td>
<td>0.07</td>
<td>-1.00</td>
<td>0.32</td>
</tr>
<tr>
<td>RANK:AOA-US</td>
<td>0.005</td>
<td>0.01</td>
<td>0.63</td>
<td>0.54</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.003</td>
<td>0.01</td>
<td>-0.42</td>
<td>0.68</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>-0.617</td>
<td>0.26</td>
<td>-2.36</td>
<td>0.03 *</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>-0.201</td>
<td>0.34</td>
<td>-0.60</td>
<td>0.56</td>
</tr>
<tr>
<td>COND(PRIME):AOA-US</td>
<td>-0.011</td>
<td>0.01</td>
<td>-0.89</td>
<td>0.38</td>
</tr>
<tr>
<td>COND(PRIME):LOR-US</td>
<td>-0.004</td>
<td>0.01</td>
<td>-0.39</td>
<td>0.70</td>
</tr>
<tr>
<td>COND(PRIME):USE-S</td>
<td>-0.010</td>
<td>0.40</td>
<td>-0.03</td>
<td>0.98</td>
</tr>
<tr>
<td>COND(PRIME):FLU-SE</td>
<td>-0.068</td>
<td>0.50</td>
<td>-0.13</td>
<td>0.89</td>
</tr>
<tr>
<td>RANK:COND(PRIME):AOA-US</td>
<td>0.025</td>
<td>0.01</td>
<td>2.10</td>
<td>0.04 *</td>
</tr>
<tr>
<td>RANK:COND(PRIME):LOR-US</td>
<td>0.017</td>
<td>0.01</td>
<td>1.93</td>
<td>0.058 †</td>
</tr>
<tr>
<td>RANK:COND(PRIME):USE-S</td>
<td>0.018</td>
<td>0.38</td>
<td>0.05</td>
<td>0.96</td>
</tr>
<tr>
<td>RANK:COND(PRIME):FLU-SE</td>
<td>0.284</td>
<td>0.47</td>
<td>0.60</td>
<td>0.55</td>
</tr>
</tbody>
</table>

† p < .1  *p < .05  ** p < .01  ***p < .001
Summary of Findings

The main objective of the structural priming experiment was to determine whether exposure to an a-priori English-specific structure—preposition stranding in English PS sentences—could facilitate syntactic processing of structurally identical (but ungrammatical) Spanish PS sentences among heritage speakers and late bilinguals and whether any measurable priming effects are influenced by individual differences in exposure, use, and proficiency for Spanish and English. The results of the group-level structural priming analysis are summarized below in Table 31. The significant effect of TRIAL at segments 3 and 4 in Spanish PS sentences shows that RTs decreased for all subjects as the experiment progressed, reflecting adaptation to the self-paced listening task. Among the remaining predictor variables, the only significant effect was the interaction between COND and GROUP at segment 3, which indicates consistently faster RTs due to within-trial cross-linguistic structural priming at the critical sentence region for late bilinguals but not heritage speakers. A lack of significance for the main effect of RANK and the interaction of RANK and GROUP suggests that repeated exposure to Spanish PS sentences had no consistent influence on syntactic processing among heritage speakers or late bilinguals at either sentence segment. A lack of significance for the interaction between RANK and COND, and the three-way interaction between RANK, COND, and GROUP also suggests that within-trial structural priming effects were not consistently influenced by repeated exposure to Spanish PS sentences in either group.

Table 31: Summary of fixed effects coefficients for the log RT group-level analysis at PS sentence segments 3 and 4.

<table>
<thead>
<tr>
<th>Fixed effect</th>
<th>Segment 3</th>
<th>Segment 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>5.941 ***</td>
<td>6.263 ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.075 *</td>
<td>-0.268 ***</td>
</tr>
<tr>
<td>GROUP(LB)</td>
<td>-0.060</td>
<td>0.133</td>
</tr>
<tr>
<td>COND(PRIME)</td>
<td>-0.035</td>
<td>-0.067</td>
</tr>
<tr>
<td>COND(PRIME):GROUP(LB)</td>
<td>-0.118 *</td>
<td>0.035</td>
</tr>
<tr>
<td>RANK</td>
<td>-0.038</td>
<td>0.067</td>
</tr>
<tr>
<td>RANK:COND(PRIME)</td>
<td>-0.014</td>
<td>-0.065</td>
</tr>
<tr>
<td>RANK:GROUP(LB)</td>
<td>0.025</td>
<td>0.046</td>
</tr>
<tr>
<td>RANK:COND(PRIME):GROUP(LB)</td>
<td>0.046</td>
<td>-0.022</td>
</tr>
</tbody>
</table>

† p < .1  * p < .05  ** p < .01  ***p < .001
The results of the individual differences analyses are summarized below in Table 32. These results show some similarities and some differences in within-trial (cross-linguistic) and cumulative (within-language, across trial) structural priming effects between heritage speakers and late bilinguals. Starting with the main effect of TRIAL, the results indicate that both groups experienced task adaptation effects over the course of the experiment, in line with the results of the group-level analysis, although this effect did not reach significance at PS sentence segment 3 for late bilinguals. Turning to the main effects of the language experience variables, the results show that among late bilinguals, overall syntactic processing of Spanish PS sentences at segment 3 or 4 was not consistently influenced by individual differences in any of these variables: Spanish-English fluency (FLU-SE), age of exposure to English (AOA-US), length of exposure to English (LOR-US), or current use of Spanish (USE-S). In contrast, overall syntactic processing for Spanish PS sentences was slower among heritage speakers who were more fluent in Spanish than English (FLU-SE) and those who had had more exposure to English (LOR-US) at the time of testing. Importantly, these effects were significant regardless of when PS sentences were encountered in the experiment or whether they were encountered in prime or control trial.

Turning to the influence of trial type (COND) on within-trial priming effects, the results show that for late bilinguals, exposure to preposition stranding in English had an immediate effect of facilitating syntactic processing at segment 3 (the critical segment) of the following structurally-identical Spanish PS sentence. The lack of significant interactions between COND and RANK or any of the language experience predictors suggests that this effect occurred consistently among late bilinguals even after repeated exposure to Spanish PS sentences. At segment 4, the lack of a significant main effect for COND or any interactions between COND and the language experience variables for late bilinguals suggests that the effects of within-trial priming at segment 3 largely disappeared by segment 4. However, the within-trial priming effect was visible at segment 4 for some late bilinguals after repeated exposure to Spanish PS sentences. This effect appeared as a mitigation of the general increase in RTs at segment 4 that accompanied repeated exposure to Spanish PS sentences for late bilinguals and was largest among late bilinguals who were exposed to English earlier in adulthood and those who had been exposed to less English.
For heritage speakers, on the other hand, the lack of any significant effects involving COND at segment 3 suggests that within-trial cross-linguistic priming had no consistent effects among individuals in this group at the critical sentence region. At segment 4, however, the significant interaction between COND and FLU-SE indicates that heritage speakers who were more fluent in Spanish than English experienced facilitated processing of Spanish PS sentences following exposure to English PS primes, while those who were more fluent in English than Spanish did not. Lastly, the significant interactions between RANK and AGE-E and RANK, COND, and AGE-E at segment 4 indicate that there was a general increase in RTs among heritage speakers following repeated exposure to Spanish PS sentences. For heritage speakers who were exposed to English later in childhood, the increase in RTs was greater and for these same individuals, the RT increase was accompanied by an increase in within-trial priming. Unlike the similar interactions involving RANK and COND for late bilinguals, which reflected a mitigated but continued increase in RTs in the prime condition following repeated exposure to PS sentences, the interaction for heritage speakers showed simultaneous decreases in RT in the prime condition and increases in RT in the control condition that accompanied repeated exposure to PS sentences.

The interactions involving RANK and COND arguably do not reflect facilitated syntactic processing due to cumulative priming per se since the effects differed for PS sentences depending on whether they occurred in prime or control trials. However, for late bilinguals, there were three interactions between RANK and the language experience predictors that revealed subtle cumulative priming effects among certain individuals in this group. At the start of the experiment, RTs at PS sentence segment 3 were similar for late bilinguals regardless of the age at which they were exposed to English (AOA-US) or their Spanish-English fluency (FLU-SE). However, with repeated exposure to PS sentences, RTs decreased more for late bilinguals who were exposed to English later in adulthood and late bilinguals who were more fluent in Spanish than English at the time of testing. Similarly, RTs at segment 4 were similar at the start of the experiment among late bilinguals regardless of their current use of Spanish (USE-S), and while repeated exposure to PS sentences led to a general increase in RTs among late bilinguals, the increase was mitigated for those who used more Spanish in their daily lives. For heritage speakers, there were no significant interactions involving RANK, which suggests that these individuals did not experience facilitated processing of Spanish PS sentences following repeated exposure to them.
Table 32: Summary of fixed effects coefficients for the log RT individual differences analysis at PS sentence segments 3 and 4 for heritage speakers and late bilinguals.

<table>
<thead>
<tr>
<th>Fixed effect</th>
<th>Segment 3</th>
<th>Segment 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>HS</td>
<td>LB</td>
</tr>
<tr>
<td></td>
<td>5.968 ***</td>
<td>5.914 ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.084 †</td>
<td>-0.059</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>1.337 †</td>
<td>-0.694</td>
</tr>
<tr>
<td>AGE-E / AOA-US</td>
<td>-0.014</td>
<td>-0.020</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.035 †</td>
<td>0.008</td>
</tr>
<tr>
<td>USE-S</td>
<td>-0.027</td>
<td>--</td>
</tr>
<tr>
<td>COND(PRIME)</td>
<td>0.024</td>
<td>-0.095 *</td>
</tr>
<tr>
<td>COND(PRIME):AGE-E / AOA-US</td>
<td>0.024</td>
<td>0.005</td>
</tr>
<tr>
<td>COND(PRIME):LOR-US</td>
<td>-0.003</td>
<td>0.000</td>
</tr>
<tr>
<td>COND(PRIME):USE-S</td>
<td>-0.051</td>
<td>--</td>
</tr>
<tr>
<td>RANK</td>
<td>-0.044</td>
<td>-0.035</td>
</tr>
<tr>
<td>RANK:COND(PRIME)</td>
<td>-0.036</td>
<td>0.003</td>
</tr>
<tr>
<td>RANK:AGE-E / AOA-US</td>
<td>0.000</td>
<td>-0.010 *</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.004</td>
<td>-0.004</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>0.043</td>
<td>--</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>0.078</td>
<td>-0.296 †</td>
</tr>
<tr>
<td>RANK:COND(PRIME):AGE-E / AOA-US</td>
<td>0.010</td>
<td>0.007</td>
</tr>
<tr>
<td>RANK:COND(PRIME):LOR-US</td>
<td>0.000</td>
<td>0.005</td>
</tr>
<tr>
<td>RANK:COND(PRIME):USE-S</td>
<td>-0.058</td>
<td>--</td>
</tr>
<tr>
<td>RANK:COND(PRIME):FLU-SE</td>
<td>-0.261</td>
<td>0.238</td>
</tr>
</tbody>
</table>

† p < .1    * p < .05    ** p < .01    ***p < .001

ACCEPTABILITY JUDGMENT RESULTS

The final experiment reported in this chapter was conducted in order to determine how heritage speakers and late bilinguals perceived the acceptability of the Spanish PS sentences that they encountered in the cross-linguistic structural priming experiment.

Data Preparation

Prior to analysis, acceptability judgments were z-score transformed by subject across all responses (including fillers) to normalize inter-subject differences in use of the 6-point Likert scale (Schütze & Sprouse, 2013). Acceptability judgment data were analyzed using linear mixed-effects models...
in R following the procedures used in the structural priming RT analysis.\textsuperscript{57} As in the RT analyses reported above, two sets of models were built to analyze the acceptability judgment data. The first set included condition (grammatical vs. ungrammatical) and subject group (heritage speakers vs. late bilinguals) as predictor variables to determine whether Spanish PS sentences were rated differently from their PP counterparts and whether there were differences in ratings between groups. The second set of models were constructed to analyze the effects of language experience, use, and proficiency on the ratings recorded within each group. The analyses reported below included 49 of the 50 subjects (28 heritage speakers, 21 late bilinguals) who were included in the RT and pupillometry analyses reported above.\textsuperscript{58}

Results

**Heritage Speakers vs. Late Bilinguals**

The mean z-score ratings for PS and PP sentences are shown below by group in Table 33 and plotted in Figure 17.\textsuperscript{59} Figure 17 shows an overall similar pattern of ratings for heritage speakers and late bilinguals in that (grammatical) PP sentences were rated higher than (ungrammatical) PS sentences by both groups. However, heritage speakers’ ratings were less extreme than the ratings given by late bilinguals for both PP and PS sentences.

<table>
<thead>
<tr>
<th>Group</th>
<th>Condition</th>
<th>Samples</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS</td>
<td>PP</td>
<td>591</td>
<td>0.44</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>PS</td>
<td>603</td>
<td>-0.22</td>
<td>0.92</td>
</tr>
<tr>
<td>LB</td>
<td>PP</td>
<td>443</td>
<td>0.76</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>PS</td>
<td>455</td>
<td>-0.75</td>
<td>0.80</td>
</tr>
</tbody>
</table>

The design of the acceptability judgment experiment and the collection of responses met all of the assumptions required to apply parametric tests in the analysis of results. The scale had 6 points and was presented such that subjects understood it to be representing a continuous concept with approximately equal intervals between the scale values 1–6. In addition, Norman (2010) presents an analysis simulation that shows analyzing Likert scale data with linear regression does not inflate the chance of Type 1 or Type 2 errors.

\textsuperscript{58} One heritage speaker did not complete the acceptability judgment experiment.

\textsuperscript{59} It is important to note that the acceptability judgment experiment contained only Spanish sentences. Subjects did not encounter any English sentences in this task.
Figure 17: Mean acceptability ratings for preposition-stranded (PS, ungrammatical) and pied-piped (PP, grammatical) sentences for heritage speakers and late bilinguals. A z-score of 0 represents the mean rating given over all stimulus items, including grammatical and ungrammatical fillers.

The linear mixed-effects model that was generated to test the effects of condition and group on z-score transformed ratings for PP and PS sentences contained the same set of fixed effect tested in the RT analyses: log-transformed trial number (TRIAL), condition (COND), group (GROUP), trial rank (RANK), and the interactions between COND, GROUP, and RANK. These variables were selected based on theoretical considerations: COND was included to test the hypothesis that Spanish PS sentences are less acceptable than their PP counterparts; GROUP was included to test whether heritage speakers rated these sentences differently than late bilinguals; and RANK was included to test whether ratings for the PP and PS sentences changed due to repeated exposure to them. TRIAL was included to control for changes in ratings over the course of the experiment due to task adaptation (i.e. differences in use of the Likert scale over the course of the experiment). For all model estimates, predictor significance was tested with the lmerTest package (Kuznetsova et al., 2017) in R with maximum likelihood t-tests using Satterthwaite approximations for degrees of freedom. The inclusion of the predictor variables in each model was justified using likelihood ratio tests to compare the goodness of fit to a model containing only the random effects structure (Baayen, 2008).
As in the RT analysis, the two predictor variables \texttt{COND} and \texttt{GROUP} were contrast coded (aka sum coded) to reduce collinearity between fixed effects involving these predictors. Likewise, the predictor variables \texttt{TRIAL} and \texttt{RANK} were mean centered to avoid collinearity with the model intercept. With this coding scheme, the model intercept represents the \textit{grand mean} z-score rating for Spanish PP and PS sentences at the mean trial number and mean rank number. For each contrast-coded predictor, the coefficient represents the difference in rating between the comparison level for that predictor (indicated in parentheses) and the grand mean rating at the mean trial number and mean rank number.

The by-group model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for \texttt{COND}, \texttt{RANK}, \texttt{TRIAL}, and the interaction between \texttt{COND} and \texttt{RANK}. Among the fixed effects, there was the expected high correlation between \texttt{RANK} and \texttt{TRIAL} ($r = -.87$); in addition, there was high correlation between the intercept and \texttt{COND} ($r = .78$); high correlation between \texttt{GROUP} and the interaction of \texttt{COND} and \texttt{GROUP} ($r = .81$); and moderate correlation between the interaction of \texttt{RANK} and \texttt{GROUP} and the interaction of \texttt{RANK}, \texttt{COND}, and \texttt{GROUP} ($r = .50$). Correlations were less than ±0.22 between all other fixed effects and interactions, indicating overall low collinearity between fixed effects. Model estimates are reported below in Table 34.

Table 34: \textit{Linear mixed-effects model estimates for heritage speakers’ and late bilinguals’ acceptability ratings of Spanish PS and PP sentences.} The intercept represents grand mean z-score transformed rating at the mean trial number and mean rank number.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>0.066</td>
<td>0.05</td>
<td>1.23</td>
<td>0.22</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.009</td>
<td>0.03</td>
<td>-0.30</td>
<td>0.76</td>
</tr>
<tr>
<td>RANK</td>
<td>0.012</td>
<td>0.03</td>
<td>0.36</td>
<td>0.72</td>
</tr>
<tr>
<td>COND(PS)</td>
<td>-1.069</td>
<td>0.12</td>
<td>-9.17</td>
<td>&lt;.001   ***</td>
</tr>
<tr>
<td>GROUP(LB)</td>
<td>-0.103</td>
<td>0.10</td>
<td>-1.00</td>
<td>0.32</td>
</tr>
<tr>
<td>RANK:COND(PS)</td>
<td>0.087</td>
<td>0.03</td>
<td>3.01</td>
<td>&lt;.01    **</td>
</tr>
<tr>
<td>RANK:GROUP(LB)</td>
<td>0.040</td>
<td>0.03</td>
<td>1.25</td>
<td>0.22</td>
</tr>
<tr>
<td>COND(PS):GROUP(LB)</td>
<td>-0.801</td>
<td>0.23</td>
<td>-3.48</td>
<td>&lt;.01    **</td>
</tr>
<tr>
<td>RANK:COND(PS):GROUP(LB)</td>
<td>0.043</td>
<td>0.06</td>
<td>0.76</td>
<td>0.45</td>
</tr>
</tbody>
</table>

$^\dagger$ $p < .1$ \quad \ast p < .05 \quad \ast\ast p < .01 \quad \ast\ast\ast p < .001
The by-group model captured 77% of the variance in z-score ratings ($R^2 = .77$) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (8) = 67.08, p < .001$). In contrast to the results of the baseline syntactic processing and structural priming analyses, the coefficient estimate for TRIAL was not significant ($\beta = -0.009, SE = 0.03, p = .76$), indicating that if there were changes in use of the Likert scale over the course of the experiment, these changes were not consistent across heritage speakers and late bilinguals. As expected, the estimate for COND indicates significantly lower ratings for PS sentences ($\beta = -1.069, SE = 0.12, p < .001$). Likewise, the significant interaction between COND and GROUP indicates that as a group, late bilinguals gave lower ratings for the PS sentences compared to the grand mean ratings ($\beta = -0.801, SE = 0.23, p < .01$). Perhaps not surprisingly, given the number of interactions in the priming analysis involving RANK, the significant interaction between RANK and COND indicates that for all subjects, ratings for the PS sentences increased with repeated exposure to these sentences ($\beta = 0.087, SE = 0.03, p < 0.01$).

To provide a acceptability ratings benchmark for heritage speakers and late bilinguals, the same mixed-effects modeling was performed for a set of object RC Spanish sentences in which the relativized NP is extracted from a complex NP complement (CNP sentences). These sentences appeared among the fillers in the same acceptability judgment task and exhibited a grammaticality contrast due to the presence or absence of the head noun of the complex NP. Unlike the PS sentences, ungrammatical CNP sentences are ungrammatical in both Spanish and English. The CNP sentences were subjected to the same analysis as the PS/PP sentences to determine whether the same pattern of ratings holds for both grammaticality contrasts. The mean z-score ratings for CNP sentences are shown below in Table 35 and plotted in Figure 18.

<table>
<thead>
<tr>
<th>Group</th>
<th>Condition</th>
<th>Samples</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS</td>
<td>Grammatical</td>
<td>328</td>
<td>-0.13</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>Ungrammatical</td>
<td>327</td>
<td>-0.94</td>
<td>0.97</td>
</tr>
<tr>
<td>LB</td>
<td>Grammatical</td>
<td>243</td>
<td>-0.17</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>Ungrammatical</td>
<td>233</td>
<td>-0.95</td>
<td>0.74</td>
</tr>
</tbody>
</table>

Table 35: Mean acceptability z-score ratings for CNP sentences for heritage speakers and late bilinguals.
Figure 18: Mean acceptability ratings for grammatical and ungrammatical CNP sentences for heritage speakers and late bilinguals. A z-score of 0 represents the mean rating given over all stimuli including all fillers and PS/PP sentences.

The mixed-effects model that was generated to test the effects of condition and group on the z-score transformed ratings for the CNP sentences contained the same fixed effect tested in the analysis of PS/PP sentences: log-transformed trial number (TRIAL), condition (COND), group (GROUP), trial rank (RANK), and the interactions between COND, GROUP, and RANK. As in the PS/PP analysis, the two predictor variables COND and GROUP were contrast coded and the predictor variables TRIAL and RANK were mean centered. With this coding scheme, the coefficient for the model intercept represents the grand mean z-score rating for grammatical and ungrammatical CNP sentences at the mean trial number and mean rank number. For each contrast-coded predictor, the coefficient represents the difference in rating between the comparison level for that predictor (indicated in parentheses) and the grand mean rating at the mean trial number and mean rank number.

The by-group model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for COND, RANK, TRIAL, and the interaction between COND and RANK. Among model fixed effects, there was the expected high correlation between the RANK and
TRIAL \((r = -0.91)\) and all other fixed-effects correlations were less than ±0.27, indicating low collinearity. For all model estimates, predictor significance was tested with the \textit{lmerTest} package \cite{Kuznetsova2017} in R with maximum likelihood t-tests using Satterthwaite approximations for degrees of freedom. The inclusion of the predictor variables in each model was justified using likelihood ratio tests to compare the goodness of fit to a model containing only the random effects structure \cite{Baayen2008}. Model estimates are shown below in Table 36.

Table 36: Linear mixed-effects model estimates for heritage speakers’ and late bilinguals’ acceptability ratings of grammatical and ungrammatical CNP sentences. The intercept represents the grand mean z-score rating for grammatical and ungrammatical CNP sentences at the mean trial number and mean rank number.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>-0.547</td>
<td>0.07</td>
<td>-7.87</td>
<td>&lt;.001   ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>0.127</td>
<td>0.07</td>
<td>1.70</td>
<td>0.099   †</td>
</tr>
<tr>
<td>RANK</td>
<td>-0.121</td>
<td>0.07</td>
<td>-1.63</td>
<td>0.11</td>
</tr>
<tr>
<td>COND(UNGRAM)</td>
<td>-0.779</td>
<td>0.10</td>
<td>-7.96</td>
<td>&lt;.001   ***</td>
</tr>
<tr>
<td>GROUP(LB)</td>
<td>-0.059</td>
<td>0.10</td>
<td>-0.59</td>
<td>0.56</td>
</tr>
<tr>
<td>RANK:COND(UNGRAM)</td>
<td>0.025</td>
<td>0.05</td>
<td>0.50</td>
<td>0.62</td>
</tr>
<tr>
<td>RANK:GROUP(LB)</td>
<td>0.018</td>
<td>0.05</td>
<td>0.36</td>
<td>0.72</td>
</tr>
<tr>
<td>COND(UNGRAM):GROUP(LB)</td>
<td>0.058</td>
<td>0.16</td>
<td>0.35</td>
<td>0.72</td>
</tr>
<tr>
<td>RANK:COND(UNGRAM):GROUP(LB)</td>
<td>-0.009</td>
<td>0.09</td>
<td>-0.09</td>
<td>0.93</td>
</tr>
</tbody>
</table>

† \(p < .1\)  *\(p < .05\)  **\(p < .01\)  ***\(p < .001\)

The by-group model captured 50\% of the variance in z-score ratings \((R^2 = .50)\) and the likelihood ratio test justified the inclusion of the fixed effects in this model \((\chi^2 (8) = 48.15, p < .001)\). Unlike in the ratings analysis for the PS/PP sentences, the coefficient estimate for TRIAL was marginally significant \((\beta = 0.127, SE = 0.07, p = .009)\), indicating that overall judgments for complex NP sentences (both grammatical and ungrammatical) increased over the course of the experiment. As expected, the estimate for the main effect of COND indicates significantly lower ratings for the ungrammatical CNP sentences compared to the grand mean rating at the mean trial and mean rank number \((\beta = -0.779, SE = 0.10, p < .001)\). Unlike the ratings analysis for the PS/PP sentences, there were no significant interactions with

\footnote{It is important to note that a mean z-score rating below 0 for the grammatical CNP sentences does not indicate that these items were judged to be unacceptable per se. Rather, a z-score of 0 indicates the mean rating over all sentences (including grammatical and ungrammatical fillers and the}
COND, suggesting that there were no consistent changes in the ratings for the ungrammatical CNP sentences among heritage speakers and late bilinguals following repeated exposure to these sentences.

**Language Exposure, Use, and Proficiency**

Given the results of the cross-linguistic structural priming analysis, that individual differences in language experience affect the magnitude of priming for Spanish PS sentences, the acceptability ratings for these sentences were analyzed separately by group to determine whether differences in language exposure, use, and proficiency had a similar effect on the acceptability of PS sentences. The linear mixed-effects models of acceptability ratings included the same language experience predictors (AGE-E/SAE-US, LOR-US, USE-S, FLU-SE) and the same experiment-related predictors (COND, RANK, TRIAL) entered in the baseline syntactic processing and structural priming analyses. The same transformations and coding scheme outlined above were applied to these variables in the acceptability ratings analysis. With this coding scheme, the coefficient for the model intercept represents the grand mean z-score transformed rating at the mean value for each centered predictor. For the contrast-coded predictor COND, the coefficient represents the difference in z-score rating between the PS sentences (PS) and the grand mean z-score rating at the mean value for each centered predictor. For each centered predictor, the coefficient estimate represents the change in z-score rating for each unit increase in the predictor.

**Heritage Speakers**

Model estimates for heritage speakers are shown below in Table 37. The HS ratings model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for COND, RANK, TRIAL, and the interaction between COND and RANK. In addition to the expected high correlation between the fixed effects of RANK and TRIAL ($r = -.92$), there were also correlations between the PS/PP sentences), so a score below 0 can only be taken as an indication that a rating was below the grand mean for all sentences. The z-score rating below 0 for the grammatical CNP sentences likely reflects the increased structural complexity of these items.

61 Since the acceptability ratings analysis was performed on all but one of the same participants who completed the priming experiment, the correlations between predictors in each group reported above in the RT analysis are qualitatively the same between the predictors entered in the ratings analysis. The transformations and centering for the predictors in the ratings analysis were calculated based on the 49 subjects included.
following fixed effects: COND and the intercept \((r = .75)\), AGE and the interaction of COND and AGE \((r = .78)\); LOR-US and the interaction of COND and LOR-US \((r = .79)\); USE-S and the interaction of COND and USE-S \((r = .79)\); FLU-SE and the interaction of COND and FLU-SE \((r = .78)\).\(^{62}\) Correlations between all other fixed effects were less than ±0.4, indicating low collinearity among these fixed effects.

This model captured 66\% of the variance in z-score ratings \((R^2 = .66)\) and the likelihood ratio test justified the inclusion of the fixed effects \((\chi^2 (20) = 38.05, p < .01)\). The highly significant main effect of COND confirms that heritage speakers’ ratings for PS sentences were significantly lower than the grand mean rating for PS and PP sentences \((\beta = -0.654, SE = 0.13, p < .001)\). The significant interaction between RANK and FLU-SE also indicates that while heritage speakers with higher fluency in Spanish than English initially gave overall higher ratings for PP and PS sentences compared to heritage speakers with higher fluency in English than Spanish, their overall ratings decreased for both sentence types with repeated exposure to both PS and PP sentences \((\beta = -0.353, SE = 0.15, p = .02)\). This interaction is plotted below in Figure 19.

The marginally significant interaction between COND and USE-S \((\beta = -1.956, SE = 1.00, p = .06)\) and the marginally significant interaction between COND and FLU-SE \((\beta = -1.928, SE = 1.13, p = .099)\) also indicate that ratings for Spanish PS sentences were lower for heritage speakers who use more Spanish and for heritage speakers who have higher Spanish fluency. These interactions are plotted below in Figure 20 and Figure 21.

---

\(^{62}\) The predictors involved in the high fixed effects correlations were retained in the model to maintain comparability with the baseline syntactic processing and structural priming models. While collinearity among fixed effects increases standard error terms and the risk of Type 2 errors involving the collinear predictors, it does not increase the chances of Type 1 errors.
Figure 19: Interaction between RANK and FLU-SE for heritage speakers’ ratings of preposition-stranded (PS) and pied-piped (PP) sentences. Values for FLU-SE reflect first quartile (-0.1), mean (0), and third quartile (0.2) for the variable for heritage speakers.

Figure 20: Interaction between COND and USE-S for heritage speakers’ ratings of PP (control) and PS (experimental) sentences. Values for USE-S represent the first quartile (-0.11), mean (0), and third quartile (0.08) for this variable for heritage speakers.
Figure 21: Interaction between COND and FLU-SE for heritage speakers' ratings of PP (control) and PS (experimental) sentences. Values for FLU-SE represent the first quartile (-0.10), mean (0), and third quartile (0.09) for this variable for heritage speakers.

Table 37: Linear mixed-effects model estimates for heritage speakers’ (n=28) acceptability ratings of PS and PP sentences. The intercept represents grand mean z-score rating for PS and PP sentences at the mean value for each centered predictor.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>0.109</td>
<td>0.07</td>
<td>1.45</td>
<td>0.16</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.029</td>
<td>0.05</td>
<td>-0.62</td>
<td>0.54</td>
</tr>
<tr>
<td>RANK</td>
<td>0.013</td>
<td>0.05</td>
<td>0.29</td>
<td>0.77</td>
</tr>
<tr>
<td>COND(PS)</td>
<td>-0.654</td>
<td>0.13</td>
<td>-5.00</td>
<td>&lt;.001   ***</td>
</tr>
<tr>
<td>AGE-E</td>
<td>0.000</td>
<td>0.03</td>
<td>-0.01</td>
<td>0.99</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.008</td>
<td>0.02</td>
<td>0.46</td>
<td>0.65</td>
</tr>
<tr>
<td>USE-S</td>
<td>-0.583</td>
<td>0.56</td>
<td>-1.04</td>
<td>0.31</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>-0.501</td>
<td>0.63</td>
<td>-0.79</td>
<td>0.44</td>
</tr>
<tr>
<td>RANK:COND(PS)</td>
<td>0.059</td>
<td>0.04</td>
<td>1.52</td>
<td>0.14</td>
</tr>
<tr>
<td>RANK:AGE-E</td>
<td>0.008</td>
<td>0.01</td>
<td>0.98</td>
<td>0.33</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.003</td>
<td>0.00</td>
<td>-0.66</td>
<td>0.51</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>-0.167</td>
<td>0.13</td>
<td>-1.27</td>
<td>0.21</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>-0.353</td>
<td>0.15</td>
<td>-2.38</td>
<td>0.02    *</td>
</tr>
<tr>
<td>COND(PS):AGE-E</td>
<td>0.021</td>
<td>0.06</td>
<td>0.35</td>
<td>0.73</td>
</tr>
<tr>
<td>COND(PS):LOR-US</td>
<td>-0.024</td>
<td>0.03</td>
<td>-0.79</td>
<td>0.44</td>
</tr>
<tr>
<td>COND(PS):USE-S</td>
<td>-1.956</td>
<td>1.00</td>
<td>-1.96</td>
<td>0.06    †</td>
</tr>
<tr>
<td>COND(PS):FLU-SE</td>
<td>-1.928</td>
<td>1.13</td>
<td>-1.70</td>
<td>0.10    †</td>
</tr>
<tr>
<td>RANK:COND(PS):AGE-E</td>
<td>-0.017</td>
<td>0.02</td>
<td>-1.07</td>
<td>0.29</td>
</tr>
<tr>
<td>RANK:COND(PS):LOR-US</td>
<td>0.005</td>
<td>0.01</td>
<td>0.64</td>
<td>0.53</td>
</tr>
<tr>
<td>RANK:COND(PS):USE-S</td>
<td>-0.011</td>
<td>0.26</td>
<td>-0.04</td>
<td>0.97</td>
</tr>
<tr>
<td>RANK:COND(PS):FLU-SE</td>
<td>-0.020</td>
<td>0.30</td>
<td>-0.07</td>
<td>0.95</td>
</tr>
</tbody>
</table>

† p < .1  * p < .05  ** p < .01  ***p < .001
Late Bilinguals

Following the same procedure in the heritage speaker ratings analysis, a mixed-effects model was created to analyze late bilinguals' acceptability ratings. Model estimates for late bilinguals are shown below in Table 38. This model was fit with maximum likelihood estimation and included the maximal random effects structure that allowed the model to converge: random intercepts for subjects and items, as well as by-subject and by-item random slopes for \texttt{COND} and \texttt{RANK} the interaction between \texttt{COND} and \texttt{RANK}.

In addition to the expected high correlation between the fixed effects of \texttt{RANK} and \texttt{TRIAL} ($r = -.69$), there was high correlation between \texttt{COND} and the intercept ($r = .87$), a moderate correlation between \texttt{COND} and the interaction of \texttt{RANK} and \texttt{COND} ($r = .47$), and also moderate to high correlations between the fixed effects \texttt{AOA-US}, \texttt{LOR-US}, \texttt{USE-S}, \texttt{FLU-SE} and interactions involving these items ($0.46 < r < 0.87$). Correlations between all other fixed effects were less than ±0.4, indicating low collinearity among these fixed effects.

The ratings model for late bilinguals captured 92% of the variance in log RT ($R^2 = .92$) and the likelihood ratio test justified the inclusion of the fixed effects in this model ($\chi^2 (20) = 56.66, p < .001$). The highly significant main effect of \texttt{COND} ($\beta = -1.487, SE = 0.16, p < .001$) indicates that late bilinguals rated Spanish PS sentences significantly lower than the grand mean for PP and PS sentences. The significant interaction between \texttt{COND} and \texttt{RANK} ($\beta = 0.111, SE = 0.05, p = .04$) indicates that for late bilinguals, ratings for PS sentences increased with repeated exposure to these sentences and the marginally significant interaction between \texttt{COND} and \texttt{LOR-US} ($\beta = 0.041, SE = 0.02, p = .078$) indicates that ratings for PS sentences were higher for late bilinguals who had had more exposure to English via longer length of residence in the U.S. These two interactions are plotted below in Figure 22 and Figure 23.

In addition, the marginally significant main effect of \texttt{FLU-SE} indicates that late bilinguals who had higher fluency in Spanish than English gave overall higher ratings for PS and PP sentences ($\beta = .755, SE = 0.43, p = .09$) and the marginally significant interaction between \texttt{RANK} and \texttt{FLU-SE} ($\beta = -0.329, SE = 0.18, p = .087$) indicates that repeated exposure to PS and PP sentences led to larger decreases in

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63 The predictors involved in the moderate and high fixed effects correlations were retained in the model to maintain comparability with the ratings model for heritage speakers and the baseline syntactic processing and structural priming models for both groups. While collinearity among fixed effects increases standard error terms and the risk of Type 2 errors involving the collinear predictors, it does not increase the chances of Type 1 errors.
ratings for these same individuals compared to late bilinguals with more higher fluency in English than Spanish. This interaction is plotted below in Figure 24.

Figure 22: Interaction between COND and RANK for late bilinguals’ ratings of PP (control) and PS (experimental) sentences.

Figure 23: Interaction between COND and LOR-US for late bilinguals’ ratings of PP (control) and PS (experimental) sentences. Values for LOR-US represent the first quartile (-4), mean (0), and third quartile (2) values for this variable for late bilinguals.
Figure 24: Interaction between RANK and FLU-SE for late bilinguals’ overall ratings of PS and PP sentences. Values for FLU-SE represent the first quartile (-0.12), mean (0), and third quartile (0.07) values for this variable for late bilinguals.

Table 38: Linear mixed-effects model estimates for late bilinguals’ (n=21) acceptability ratings of PS and PP sentences. The intercept represents grand mean z-score for PS and PP sentences at the mean value for each centered predictor.

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>0.019</td>
<td>0.06</td>
<td>0.34</td>
<td>0.74</td>
</tr>
<tr>
<td>TRIAL</td>
<td>0.015</td>
<td>0.03</td>
<td>0.59</td>
<td>0.56</td>
</tr>
<tr>
<td>RANK</td>
<td>0.006</td>
<td>0.03</td>
<td>0.17</td>
<td>0.86</td>
</tr>
<tr>
<td>COND(PS)</td>
<td>-1.487</td>
<td>0.16</td>
<td>-9.43</td>
<td>&lt;.001***</td>
</tr>
<tr>
<td>AOA-US</td>
<td>-0.006</td>
<td>0.01</td>
<td>-0.61</td>
<td>0.55</td>
</tr>
<tr>
<td>LOR_US</td>
<td>0.013</td>
<td>0.01</td>
<td>1.61</td>
<td>0.12</td>
</tr>
<tr>
<td>USE_S</td>
<td>0.014</td>
<td>0.03</td>
<td>0.04</td>
<td>0.97</td>
</tr>
<tr>
<td>FLU_SE</td>
<td>0.755</td>
<td>0.43</td>
<td>1.77</td>
<td>0.09†</td>
</tr>
<tr>
<td>RANK:COND(PS)</td>
<td>0.111</td>
<td>0.05</td>
<td>2.18</td>
<td>0.04*</td>
</tr>
<tr>
<td>RANK:AOA-US</td>
<td>-0.006</td>
<td>0.00</td>
<td>-1.39</td>
<td>0.18</td>
</tr>
<tr>
<td>RANK:LOR_US</td>
<td>-0.004</td>
<td>0.00</td>
<td>-1.03</td>
<td>0.32</td>
</tr>
<tr>
<td>RANK:USE_S</td>
<td>-0.039</td>
<td>0.14</td>
<td>-0.28</td>
<td>0.79</td>
</tr>
<tr>
<td>RANK:FLU_SE</td>
<td>-0.329</td>
<td>0.18</td>
<td>-1.79</td>
<td>0.087†</td>
</tr>
<tr>
<td>COND(PS):AOA-US</td>
<td>-0.035</td>
<td>0.03</td>
<td>-1.21</td>
<td>0.24</td>
</tr>
<tr>
<td>COND(PS):LOR_US</td>
<td>0.041</td>
<td>0.02</td>
<td>1.85</td>
<td>0.078†</td>
</tr>
<tr>
<td>COND(PS):USE_S</td>
<td>0.465</td>
<td>0.91</td>
<td>0.51</td>
<td>0.61</td>
</tr>
<tr>
<td>COND(PS):FLU_SE</td>
<td>1.122</td>
<td>1.18</td>
<td>0.95</td>
<td>0.35</td>
</tr>
<tr>
<td>RANK:COND(PS):AOA-US</td>
<td>-0.007</td>
<td>0.01</td>
<td>-0.76</td>
<td>0.46</td>
</tr>
<tr>
<td>RANK:COND(PS):LOR_US</td>
<td>-0.002</td>
<td>0.01</td>
<td>-0.30</td>
<td>0.77</td>
</tr>
<tr>
<td>RANK:COND(PS):USE_S</td>
<td>-0.173</td>
<td>0.29</td>
<td>-0.61</td>
<td>0.55</td>
</tr>
<tr>
<td>RANK:COND(PS):FLU_SE</td>
<td>-0.480</td>
<td>0.37</td>
<td>-1.29</td>
<td>0.21</td>
</tr>
</tbody>
</table>

† p < .1  * p < .05  ** p < .01  ***p < .001
Summary of Findings

The results of the acceptability ratings by-group analysis are summarized below in Table 39. The comparison of ratings for PS/PP sentences and CNP sentences between heritage speakers and late bilinguals showed that Spanish PS and ungrammatical CNP sentences were rated significantly lower than their grammatical counterparts by both groups. While the significant interaction of COND and GROUP in the PS/PP results indicate that late bilinguals rated PS sentences significantly lower than did heritage speakers, this was not the case for ungrammatical CNP sentences. In addition, the significant interaction of RANK and COND in the PS/PP results indicates an overall increase in ratings for PS sentences across groups following repeated exposure to these sentences, although this did not occur for ungrammatical CNP sentences.64

Table 39: Summary of fixed effects for the acceptability ratings group-level analysis for PS/PP and CNP sentences.

<table>
<thead>
<tr>
<th>Fixed effect</th>
<th>PS/PP</th>
<th>CNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>0.066</td>
<td>-0.547 ***</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.009</td>
<td>0.127 †</td>
</tr>
<tr>
<td>RANK</td>
<td>0.012</td>
<td>-0.121</td>
</tr>
<tr>
<td>COND(PS / UNGRAM)</td>
<td>-1.069 ***</td>
<td>-0.779 ***</td>
</tr>
<tr>
<td>GROUP(LB)</td>
<td>-0.103</td>
<td>-0.059</td>
</tr>
<tr>
<td>RANK:COND(PS / UNGRAM)</td>
<td>0.087 **</td>
<td>0.025</td>
</tr>
<tr>
<td>RANK:GROUP(LB)</td>
<td>0.04</td>
<td>0.018</td>
</tr>
<tr>
<td>COND(PS / UNGRAM):GROUP(LB)</td>
<td>-0.801 **</td>
<td>0.058</td>
</tr>
<tr>
<td>RANK:COND(PS / UNGRAM):GROUP(LB)</td>
<td>0.043</td>
<td>-0.009</td>
</tr>
</tbody>
</table>

† p < .1     * p < .05     ** p < .01     ***p < .001

The fixed-effects coefficients for the individual differences analyses of acceptability ratings that included the language experience predictor variables are summarized below in Table 40. These analyses showed that individual differences in language exposure, use, and proficiency among heritage speakers and late bilinguals modulated acceptability ratings for PS and PP sentences. Starting with main effects related to the language experience variables, the main effect of FLU-SE indicates that overall ratings were significantly higher among late bilinguals who had higher fluency in Spanish than English although the

64 As the individual differences analyses showed, the increases in ratings for PS sentences following repeated exposure to them were driven by late bilinguals.
significant interaction between RANK and FLU-SE shows that this effect was driven mainly by higher ratings among these late bilinguals earlier in the experiment. While there was no consistent differences in ratings among heritage speakers related to any of the language experience variables, including FLU-SE, the significant interaction between RANK and FLU-SE indicates that, like in the case of late bilinguals, overall ratings for heritage speakers with higher fluency in Spanish than English decreased more with repeated exposure to PP and PS sentences.

Turning to differences in ratings between Spanish PS and PP sentences, the significant main effects of COND for both groups confirm the result of the by-group analysis that Spanish PS sentences were rated significantly lower than Spanish PP sentences by both heritage speakers and late bilinguals. Among heritage speakers, ratings for PS sentences were influenced by current Spanish use and Spanish-English fluency: heritage speakers who use Spanish more often and individuals with higher fluency in Spanish than English gave lower ratings for PS sentences compared to heritage speakers who use Spanish less often and have higher fluency in English than Spanish. For late bilinguals, on the other hand, ratings for PS sentences were influenced only by amount of English exposure: late bilinguals who had been exposed to more English (via longer length of residence in the U.S.) gave higher ratings for PS sentences compared to late bilinguals who had received less exposure to English. Lastly, late bilinguals, but not heritage speakers, gave higher ratings for PS sentences following repeated exposure to these sentences, reflected in the significant interaction between RANK and COND for late bilinguals.
Table 40: Summary of fixed effects for the acceptability ratings individual differences analysis for PS/PP sentences. The intercepts represent the grand mean z-score rating for PS and PP sentences within each group.

<table>
<thead>
<tr>
<th>Fixed effect</th>
<th>HS</th>
<th>LB</th>
</tr>
</thead>
<tbody>
<tr>
<td>(INTERCEPT)</td>
<td>0.109</td>
<td>0.019</td>
</tr>
<tr>
<td>TRIAL</td>
<td>-0.029</td>
<td>0.015</td>
</tr>
<tr>
<td>AGE-E / AOA-US</td>
<td>0.000</td>
<td>-0.006</td>
</tr>
<tr>
<td>LOR-US</td>
<td>0.008</td>
<td>0.013</td>
</tr>
<tr>
<td>USE-S</td>
<td>-0.583</td>
<td>0.014</td>
</tr>
<tr>
<td>FLU-SE</td>
<td>-0.501</td>
<td>0.755 †</td>
</tr>
<tr>
<td>COND(PS)</td>
<td>-0.654 ***</td>
<td>-1.487 ***</td>
</tr>
<tr>
<td>COND(PS):AGE-E / AOA-US</td>
<td>0.021</td>
<td>-0.035</td>
</tr>
<tr>
<td>COND(PS):LOR-US</td>
<td>-0.024</td>
<td>0.041 †</td>
</tr>
<tr>
<td>COND(PS):USE-S</td>
<td>-1.956 †</td>
<td>0.465</td>
</tr>
<tr>
<td>COND(PS):FLU-SE</td>
<td>-1.928 †</td>
<td>1.122</td>
</tr>
<tr>
<td>RANK</td>
<td>0.013</td>
<td>0.006</td>
</tr>
<tr>
<td>RANK:COND(PS)</td>
<td>0.059</td>
<td>0.111 *</td>
</tr>
<tr>
<td>RANK:AGE-E / AOA-US</td>
<td>0.008</td>
<td>-0.006</td>
</tr>
<tr>
<td>RANK:LOR-US</td>
<td>-0.003</td>
<td>-0.004</td>
</tr>
<tr>
<td>RANK:USE-S</td>
<td>-0.167</td>
<td>-0.039</td>
</tr>
<tr>
<td>RANK:FLU-SE</td>
<td>-0.353 *</td>
<td>-0.329 †</td>
</tr>
<tr>
<td>RANK:COND(PS):AGE-E / AOA-US</td>
<td>-0.017</td>
<td>-0.007</td>
</tr>
<tr>
<td>RANK:COND(PS):LOR-US</td>
<td>0.005</td>
<td>-0.002</td>
</tr>
<tr>
<td>RANK:COND(PS):USE-S</td>
<td>-0.011</td>
<td>-0.173</td>
</tr>
<tr>
<td>RANK:COND(PS):FLU-SE</td>
<td>-0.020</td>
<td>-0.480</td>
</tr>
</tbody>
</table>

† p < .1     *p < .05     ** p < .01     ***p < .001

RESULTS SUMMARY

The results obtained for the baseline syntactic processing, structural priming, and acceptability judgment experiments revealed some similarities and some differences between heritage speakers and late bilinguals. Starting with the results of the baseline syntactic processing group-level analysis, the main findings showed that overall syntactic processing of grammatical Spanish RC sentences was essentially the same for heritage speakers and late bilinguals. Both groups showed very high accuracy rates on the comprehension questions for these sentences, suggesting that they understood them to the same degree, and the patterns of RTs measured during the final two sentence regions—the critical region where the filler-gap dependency between the relativized NP and RC verb is completed (RC sentence segment 3) and the following spillover region containing a RC VP-modifying adjunct phrase (RC sentence segment 4)—were qualitatively the same. While RTs did not differ between groups at the critical sentence...
region, both groups showed increases in RTs at the spillover region, although RTs were longer for late bilinguals, indicating slower syntactic processing for this group compared to heritage speakers.

The baseline syntactic processing individual differences analyses showed qualitative differences between late bilinguals and heritage speakers. Among heritage speakers, syntactic processing speed was influenced by Spanish-English fluency and age of English acquisition: heritage speakers who were exposed to English later in childhood (and were therefore monolingual Spanish speakers for longer) showed significantly faster processing at the spillover region, while heritage speakers who were more fluent in Spanish than English showed significantly slower processing at the critical region and the spillover region. Among late bilinguals, Spanish-English fluency and age of English acquisition did not predict processing speed, although current Spanish use and amount of exposure to English did: late bilinguals who used more Spanish in daily interactions showed faster processing at the spillover region, while late bilinguals who had been exposed to more English showed slower processing at the spillover region. The significant interactions with RANK for both of these predictors showed that although syntactic processing was initially slower for late bilinguals who had been exposed to more English, processing speed increased more with repeated exposure to these sentences for these individuals, and while syntactic processing speed at the start of the experiment was not predicted by amount of Spanish use, processing speed for late bilinguals who used more Spanish increased to a greater degree with repeated exposure to RC sentences. While these interactions show that these late bilinguals were sensitive to cumulative priming effects in the form of reductions in processing speed at the spillover region, there was no evidence of cumulative structural priming of the Spanish RC sentences at either sentence region for heritage speakers.

Turning to the structural priming analyses, the main finding is that among heritage speakers, there was an effect of within-trial cross-linguistic structural priming for Spanish PS sentences although this effect was not consistent. Heritage speakers who were more fluent in Spanish than English showed a within-trial priming effect in the form of faster processing at the spillover region following exposure to English PS sentences but heritage speakers who were more fluent in English than Spanish did not show this effect at either region. This aligns with the findings of the baseline syntactic processing analysis in that heritage speakers who were more fluent in Spanish than English patterned like late bilinguals in both
analyses—showing longer processing for the (grammatical) RC sentences and sensitivity to within-trial priming of the (ungrammatical) PS sentences. In addition, heritage speakers who were exposed to English later in childhood also showed an effect of within-trial cross-linguistic priming, although this only appeared after repeated exposure to Spanish PS sentences. Late bilinguals, on the other hand, were generally sensitive to within-trial cross-linguistic structural priming for Spanish PS sentences, which appeared as faster syntactic processing at the critical sentence region following exposure to English PS sentences. Importantly, this effect was not modulated by repeated exposure to Spanish PS sentences or differences in the language experience variables. While the syntactic processing advantage (lower RTs) due to within-trial priming effects generally disappeared for late bilinguals by the spillover region, the facilitative effect persisted through this region for some late bilinguals: those who were exposed to English earlier in adulthood and those who had been exposed to less English, although the effect only emerged after repeated exposures to Spanish PS sentences in both cases. Importantly, each of interactions between RANK and COND shows that repeated exposure to Spanish PS sentences did not diminish the within-trial priming effects following exposure to English PS sentences—rather, repeated exposure to Spanish PS sentences led to an emergence of within-trial priming effects at the spillover region for some heritage speakers and late bilinguals.

Beyond the influence that repeated exposure to Spanish PS sentences had on the emergence of within-trial priming effects for some heritage speakers, there was no indication that heritage speakers experienced general increases in processing speed due to cumulative (within-language) priming effects for Spanish PS sentences at either sentence region. This was not the case for late bilinguals. While repeated exposure to PS sentences led to overall increases in processing time at the spillover region among late bilinguals, this increase was mitigated for late bilinguals who used more Spanish in daily interactions. This pattern and the lack of general cumulative priming effects among heritage speakers are consistent with the findings of the baseline syntactic processing analysis with (grammatical) Spanish RC sentences. However, unlike for the RC sentences, late bilinguals also showed sensitivity to cumulative priming for Spanish PS sentences at the critical region, which appeared as an increase of processing speed that accompanied repeated exposure to Spanish PS sentences for late bilinguals who were exposed to English later in adulthood and those who were more fluent in Spanish than English.
The other pertinent findings from the priming analysis showed that for late bilinguals, there were no significant differences in overall processing speed of the (ungrammatical) Spanish PS sentences that were related to individual differences in language exposure, use, and proficiency. This finding contrasts with the results of the baseline syntactic processing analysis, which show that overall syntactic processing of the (grammatical) RC sentences was faster for late bilinguals who used more Spanish in daily interactions and slower for late bilinguals who had been exposed to more English. Syntactic processing of RC and PS sentences was more similar for heritage speakers in that for both sentence types, there were overall differences in processing speed among heritage speakers related to individual differences in language exposure and Spanish-English fluency. While syntactic processing for (grammatical) RC and (ungrammatical) PS sentences was slower for heritage speakers who had higher fluency in Spanish than English (as noted above), processing of PS sentences was also slower for heritage speakers who had been exposed to more English while processing of RC sentences was faster for heritage speakers who acquired English later in childhood.

Lastly, the findings of the acceptability judgment analysis showed some patterns for heritage speakers and late bilinguals that were mostly consistent with the findings of the baseline syntactic processing and structural priming analyses. While heritage speakers and late bilinguals consistently rated Spanish PS sentences to be less acceptable than Spanish PP sentences, ratings for PS sentences were significantly lower for late bilinguals than heritage speakers. Heritage speakers who were more fluent in Spanish than English once again patterned like late bilinguals in that they gave significantly lower ratings to PS sentences compared to heritage speakers who were more fluent in English than Spanish. While average ratings across PS and PP sentences for late bilinguals who were more fluent in Spanish than English were initially higher than the ratings given by late bilinguals who were more fluent in English than Spanish, repeated exposure to PS and PP sentences lead to significant decreases in average ratings. Again, the same pattern was observed for heritage speakers who were more fluent in Spanish than English. Also in line with the priming results, late bilinguals gave significantly higher ratings to Spanish PS sentences following repeated exposure to them while this was not observed for heritage speakers. This pattern mirrors the cumulative priming results that showed repeated exposure to Spanish PS sentences had no consistent effect on syntactic processing of these sentences for heritage speakers, but it did
facilitate processing of Spanish PS sentences for late bilinguals who were exposed to English later in adulthood, used more Spanish in daily interactions, and had higher fluency in Spanish than English. Lastly, the acceptability ratings analysis showed that among heritage speakers, Spanish PS sentences were rated lower by those who used more Spanish in daily interactions, while among late bilinguals, those who had been exposed to more English gave higher ratings for these sentences. In contrast to the ratings given for the PS/PP sentences, heritage speakers and late bilinguals give nearly identical ratings for the grammatical and ungrammatical CNP sentences.

Taken together, the findings from the three analyses reported above show some similarities and some differences between heritage speakers and late bilinguals. Qualitatively, heritage speakers with higher fluency in Spanish than English showed similar results to late bilinguals in the baseline syntactic processing, structural priming, and acceptability judgment experiments: Like late bilinguals, these heritage speakers were slower to process Spanish RC sentences and they gave lower ratings to Spanish PS sentences in the acceptability judgment task, but they also showed facilitated processing for these sentences following exposure to English PS sentences. It is noteworthy that Spanish-English fluency and age of English acquisition were the only language experience variables that predicted baseline syntactic processing and within-trial priming for heritage speakers. For the acceptability ratings, heritage speakers’ Spanish-English fluency was also predictive as was current Spanish use, but age of English acquisition was not. Among late bilinguals, the influence of individual differences in language exposure, use, and proficiency was less consistent across the three analyses. While amount of exposure to English was predictive in each analysis, Spanish-English fluency was only predictive of acceptability ratings and cumulative priming for PS but not RC sentences. Late bilinguals’ Spanish use, on the other hand, was predictive of cumulative priming for PS and RC sentences but did not influence ratings, while age of English acquisition did not predict ratings or processing of RC sentences but it did influence cumulative priming of PS sentences. Aside from the within-group differences in how syntactic processing, within-trial and cumulative priming, and ratings were influenced by language experience, the major difference between heritage speakers and late bilinguals is that late bilinguals showed cumulative priming effects and overall increases in ratings for Spanish PS sentences following repeated exposure to them, while heritage speakers showed neither effect.
CHAPTER 6: DISCUSSION AND CONCLUSIONS

L1 BASELINE SYNTACTIC PROCESSING

The major finding of the baseline syntactic processing analysis was that heritage speakers and late bilinguals processed grammatical Spanish RC sentences similarly. While both groups showed similarly high comprehension rates of (grammatical) Spanish object RC sentences and qualitatively similar RTs at each sentence region, processing was faster for heritage speakers than late bilinguals at the sentence-final segment (segment 4). In light of the limited research that has focused on heritage speakers’ production and comprehension of RC structures, this finding is not too surprising. Whereas low proficiency heritage speakers have been found to show difficulties in producing subject and object RC structures in Korean (Lee-Ellis, 2011) and low accuracy in comprehending object RC sentences in Russian (Polinsky, 2011), high proficiency heritage Spanish speakers have been shown to pattern like Spanish monolinguals in their attachment preferences for ambiguous Spanish RCs (Jegerski et al., 2016). Jegerski et al.’s (2016) finding that heritage speakers showed Spanish monolingual-like (high) attachment preferences for ambiguous Spanish RC sentences was unexpected given previous work that has shown shifts to English-like (low attachment) preferences for the same types of Spanish sentences among late Spanish-English bilinguals who were immersed in English for far shorter periods (Dussias, 2004; Dussias & Sagarra, 2007). Along with Jegerski et al.’s (2016) findings, the results of the baseline syntactic processing analysis in the present study provide further evidence that among higher proficiency heritage speakers, syntactic processing may not differ from that of late bilinguals.

It seems unlikely that slower syntactic processing among the late bilinguals examined here can be explained by differences in any of the language experience variables included in the baseline syntactic processing analysis. Compared to heritage speakers, late bilinguals on average reported using more Spanish in daily interactions, spent more of their lives immersed in Spanish, had been exposed to less English, and had higher fluency in Spanish than English. None of these characteristics seem particularly likely to lead to slower syntactic processing in L1 Spanish. One possible explanation could lie in the small age differences between the heritage speakers and late bilinguals tested in the present study. Although age ranges were similar between the two groups, the mean age was roughly 6 years older for late
bilinguals than heritage speakers. Research has shown that syntactic processing slows with age (e.g., Caplan, DeDe, Waters, Michaud, & Tripodis, 2011), however, it seems unlikely that differences in processing speed in the baseline syntactic analysis resulted from age differences between heritage speakers and late bilinguals in the current study since the majority of subjects were in their 20s or 30s.

A more plausible explanation could lie in the nature of the self-paced listening task in which the Spanish RC sentences were encountered. In this task, subjects were presented with approximately equal numbers of Spanish and English sentences that were intermixed throughout the experiment. The design was such that subjects were not alerted to the language of the upcoming sentence and they had to continually switch back and forth between English and Spanish from one sentence to the next. It is possible that this continual language switching was costlier for late bilinguals than for heritage speakers, which resulted in overall slower syntactic processing. A number of studies have found evidence of enhanced performance in non-linguistic tasks requiring inhibition of irrelevant information or task switching among (typically early) highly proficient bilinguals (Kroll & Bialystok, 2013; Moreno et al., 2008), which has generally been attributed to the fine-tuning of the control mechanism involved in years of language selection and inhibition among these individuals (Bialystok, 2001). The heritage speakers tested in the present study—simultaneous or early sequential bilinguals—had spent the majority of their lives in the U.S. where they frequently switched between Spanish and English depending on their interlocutors and communicative contexts, whereas the late bilinguals may have experienced less frequent language switching, especially before arriving to the U.S. as adults. As a result of these differences in bilingual development, the overall slower syntactic processing that was found for late bilinguals could reflect costlier language switching.

One complication with this interpretation is that heritage speakers who were more fluent in Spanish than English also showed slower processing compared to heritage speakers who were less fluent in Spanish than English. While this finding suggests that these heritage speakers processed the RC sentences more like late bilinguals, slower processing among heritage speakers is not easily explained by individual differences in the ease of switching between Spanish and English. However, other findings from experimental studies on executive control among bilinguals suggests that inhibition of a bilingual’s dominant language is more costly than inhibition of the non-dominant language and, importantly, when
switching into the dominant language this inhibition is also more costly to overcome (Meuter & Allport, 1999; Rodriguez-Fornells et al., 2006). The relationship between differences in Spanish-English fluency among heritage speakers and processing speed for the Spanish RC sentences aligns with these findings. Given the continuous switching between English and Spanish in the present study, it is reasonable to hypothesize that while processing Spanish RC sentences, overcoming previous inhibition of Spanish was on average costlier for late bilinguals than heritage speakers and likewise, among heritage speakers, overcoming Spanish inhibition was costlier for those who were more fluent in Spanish than English. A similar explanation was put forth by Costa and Santesteban (2004) in interpreting their findings from a set of language switching experiments that showed the cost of overcoming L1 inhibition during lexical retrieval was lower for highly proficient early bilinguals compared to L2 learners who were more dominant in their L1 than L2 (see also Meuter and Allport (1999) and Misra, Guo, Bobb, and Kroll (2012)). As the present study was not designed to test the costs associated with language inhibition and switching between heritage speakers and late bilinguals, further studies will be required to test this hypothesis.  

L1 CUMULATIVE STRUCTURAL PRIMING

A second important finding from the analysis of syntactic processing for (grammatical) Spanish object RC sentences was that some late bilinguals, but not heritage speakers, showed faster syntactic processing at the sentence final segment (segment 4) with repeated exposure to these sentences. This result is consistent with previous work on cumulative priming that has shown that syntactic processing for grammatical structures that are uncommon or that are a priori more difficult to processes becomes easier with repeated exposure to them (e.g., Fine & Jaeger, 2016; Fine, Jaeger, Farmer, & Qian, 2013; and references therein).

An additional possible source of RT differences could lie in the characteristics of the RC stimuli themselves. In Spanish object RCs the subject can appear either pre- or post-verbally (e.g., Estas son las camisas que Sofia regaló a la iglesia. (pre-verbal RC subject) or Estas son las camisas que regaló Sofia a la iglesia. (post-verbal RC subject) "These are the shirts that Sofia donated to the church.") (Zagona, 2002). The RC sentences used in the present study all contained pre-verbal RC subjects. While the naturalness of each sentence was verified by a late bilingual and heritage speaker, it is possible that the pre-verbal RC subjects in the stimuli used here led to processing differences between late bilinguals and heritage speakers.
The effect of cumulative priming on syntactic processing for Spanish object RC sentences was not consistent across late bilinguals, however. The significant interaction between RANK and EXP-E showed that repeated exposure to these sentences led to faster syntactic processing among late bilinguals who had been exposed to more English and showed initially slower processing for these sentences at the start of the experiment. Following extensive exposure to English, it is possible that syntactic processing for complex Spanish sentences becomes more difficult. Since object RC sentences are known to be somewhat more difficult to process across languages (e.g., Betancort, Carreiras, & Sturt, 2009; Just & Carpenter, 1993; King & Just, 1991; Müller, King, & Kutas, 1997; Traxler, Morris, & Seely, 2002) it is not surprising that the Spanish RC sentences tested here became easier to process with repeated exposure to them, especially for late bilinguals who had spent more time living in an English-speaking environment.\textsuperscript{66}

The second interaction involving cumulative priming for the RC sentences is less straightforwardly accounted for. This interaction showed a larger cumulative priming effect for late bilinguals who used Spanish more often in daily interactions (USE-S). If cumulative priming reflects facilitated syntactic processing via implicit learning, as is generally argued (Bock & Griffin, 2000; Kaschak, Kutta, & Jones, 2011), it is not clear why late bilinguals who used less Spanish in daily interactions experienced a lesser or no facilitative effect compared to late bilinguals who used more Spanish in daily interactions. In the case of processing grammatical but infrequent (i.e., unexpected) syntactic structures, cumulative priming effects have been interpreted an indication that listeners update their expectations about the probability of encountering a given structure based on recent input (Fine & Jaeger, 2013, 2016; Fine et al., 2013). Under this interpretation, the cumulative priming effects for late bilinguals who used more Spanish in daily interactions may signify that these individuals are more sensitive to changes in the frequency of occurrence of syntactic structures.

The analysis of syntactic processing for the (ungrammatical) Spanish PS sentences also revealed cumulative priming effects that were similarly related to late bilinguals’ use of Spanish. While processing

\textsuperscript{66} See also Wells, Christiansen, Race, Acheson, and MacDonald (2009) for evidence that processing of object RC sentences in English improves following repeated exposure to this structure over several weeks.
at the sentence-final segment (segment 4) generally (but not significantly) slowed for late bilinguals with repeated exposure to Spanish PS sentences, processing slowed less for late bilinguals who used more Spanish. By the end of the experiment, these individuals were processing PS sentence segment 4 significantly faster than late bilinguals who used less Spanish in daily interactions. At the critical region of Spanish PS sentences (segment 3), processing speed also became significantly faster with repeated exposure to these sentences for late bilinguals who acquired English later in adulthood and late bilinguals who had higher fluency in Spanish than English. Across the Spanish RC and PS sentences, the interactions involving cumulative priming patterned similarly in that late bilinguals who had ‘stronger’ Spanish at the time of testing (increased use, higher fluency, and shorter exposure to English) showed cumulative priming effects—faster syntactic processing with repeated exposure to these sentences.

However, it is important to recall that unlike the Spanish RC sentences, the Spanish PS sentences are a priori ungrammatical in Spanish and the late bilinguals tested in the present study were unlikely to have heard many instances of this structure in Spanish. Considering the evidence that repeated exposure to a novel syntactic structure can facilitate comprehension and syntactic processing of that structure among monolinguals (Fraundorf & Jaeger, 2016; Kaschak & Glenberg, 2004), this finding suggests that these late bilinguals learned to process Spanish PS sentences over the course of the experiment. Why this effect appeared only for late bilinguals who had higher Spanish fluency, used Spanish more often, and were exposed to English later in adulthood is not entirely clear, but it may be linked to amount of exposure to preposition stranding in English. While all participants in the present study were familiar with preposition stranding, it is possible that this structure was more unexpected or more difficult to process for late bilinguals who had higher Spanish fluency, used Spanish more often, and acquired English later in adulthood. It follows from this assumption that the effect of repeated exposure to these sentences on implicitly learning to process them would be larger for these individuals than for late bilinguals who had higher fluency in English than Spanish, used English more often, and acquired English
earlier in adulthood and, as a result, had likely been exposed to many more instances of preposition stranding.67

Cumulative priming effects observed for a particular structure have been interpreted both as evidence that implicit learning of the associated processing procedures has taken place (in the case of processing novel structures) (Fraundorf & Jaeger, 2016; Kaschak & Glenberg, 2004) and as an indication of changes in the expected probability of encountering the structure (in the case of processing grammatical but less frequent structures) (Fine & Jaeger, 2013, 2016; Fine et al., 2013). Unfortunately, the design of the present study does not provide the information needed to tease apart these possible explanations for the cumulative priming effects observed for Spanish PS sentences among late bilinguals. Given that these sentences are a priori ungrammatical in Spanish, the assumption is that cumulative priming effects reflect implicitly learning to process these structures. However, the cumulative priming effects observed in the present study are also compatible with the notion that late bilinguals who showed an effect already possessed the relevant syntactic processing procedures but were more sensitive to the changes in the statistical probability of encountering this structure compared to heritage speakers and late bilinguals who did not show the cumulative priming effect.68

As with the (grammatical) Spanish RC sentences, there was no evidence that heritage speakers experienced cumulative priming effects for the (ungrammatical) Spanish PS sentences. Since cumulative structural priming in a heritage language has not been studied so far, there is no benchmark for interpreting the lack of cumulative priming effects among heritage speakers for either sentence type. Considering the explanations of cumulative priming in terms of implicit learning of processing procedures and tuning of syntactic expectations, the lack of cumulative priming effects among heritage speakers could suggest that encountering the Spanish RC and PS sentences either did not change their expectations about the probability of encountering this structure in subsequent stimuli or encountering

67 See (Fraundorf & Jaeger, 2016) for a similar account of cumulative priming for the needs construction in English among subjects who had never encountered this structure but a lack of cumulative priming for subjects who were familiar with the construction.

68 Crucially, the second explanation, in which the cumulative priming effect among late bilinguals reflects increases sensitivity to changes in frequency of occurrence for the Spanish PS sentences, rests on the assumption that frequency information is tracked similarly for grammatical and a priori ungrammatical structures. It is not clear at present whether this is the case.
these sentences did not result in implicit learning of the associated syntactic processing routines. If the Spanish RC and PS sentences were not particularly difficult for heritage speakers to process, repeated exposure to these sentences would do little to further facilitate their processing. It is not clear why (grammatical) Spanish object RC sentences would be easier to process for heritage speakers compared to late bilinguals, but the baseline syntactic processing analysis suggests that this might actually be the case for the individuals tested in the present study. While syntactic processing of RC sentences was qualitatively the same for heritage speakers and late bilinguals, late bilinguals were significantly slower to process the sentence-final segment. Based on this finding, it is possible that the relatively ‘easy’ processing of RC sentences for heritage speakers was not further facilitated by repeated exposure to them. However, one additional finding complicates this interpretation—heritage speakers who had higher fluency in Spanish than English were found to pattern like late bilinguals across the analyses of baseline syntactic processing, within-trial cross-linguistic priming, and acceptability judgments. Given these similarities, it is unclear why these heritage speakers did not also experience cumulative priming effects for either the RC or PS sentences.

L2 INFLUENCE ON L1 SYNTACTIC PROCESSING

The main research question of the present study asked whether exposure to preposition stranding in English could facilitate heritage speakers’ syntactic processing of structurally-parallel (ungrammatical) Spanish sentences. The results of the within-trial cross-linguistic structural priming analysis indicate that the answer is a qualified yes. Among heritage speakers, syntactic processing for the sentence-final segment (segment 4) of Spanish PS sentences was faster following exposure to English PS sentences, although the effect only reached significance for heritage speakers who had higher fluency in Spanish than English. For heritage speakers who had lower fluency in Spanish than English, within-trial cross-linguistic priming of Spanish PS sentences was not observed. Importantly, the within-trial priming effect that was observed for heritage speakers with higher fluency in Spanish was not influenced by repeated exposure to Spanish PS sentences, which suggests that the priming effect is due to residual activation of the relevant syntactic representations rather than implicit learning.

Following the interpretation in the literature, that cross-linguistic within-trial priming reflects the residual activation of syntactic representations or structure building procedures that are shared between a
bilingual’s two languages (e.g., Hartsuiker et al., 2004), the hypothesis for the present study was that if exposure to English PS sentences could prime comprehension of Spanish PS sentences, this would most likely occur for heritage speakers who had acquired English at an earlier age, had been exposed to English for more of their lives, used more English than Spanish, and had higher fluency in English than Spanish. This hypothesis was based on the assumption that the syntactic representations or structure building procedures involved in the comprehension of preposition stranding would most likely be shared among heritage speakers with the ‘strongest’ English (i.e. greater use, fluency, and exposure to English). The findings of the cross-linguistic within-trial priming analysis indicate that this was not the case.

One possible explanation for the absence of within-trial cross-linguistic priming effects among heritage speakers who had lower fluency in Spanish than English is that for these individuals, Spanish PS sentences were not exceptionally difficult to process and as a result, exposure to preposition stranding in the English PS primes did not further facilitate their processing. This interpretation is supported by two other findings from the within-trial priming and acceptability judgment analyses. Among heritage speakers, the marginally significant main effect of Spanish-English fluency at the critical region in Spanish PS sentences—containing the RC verb, direct object, and stranded preposition—indicates that regardless of whether the Spanish PS sentence appeared in a prime or control trial, syntactic processing of this segment was significantly faster for the same heritage speakers who failed to show within-trial priming effects. The relationship between higher English fluency and faster overall processing at the critical region in Spanish PS sentences was also paralleled in the acceptability judgment results (discussed below) that showed higher ratings for Spanish PS sentences among heritage speakers with lower fluency in Spanish than English compared to lower ratings given by heritage speakers with higher fluency in Spanish than English. Paired with the within-trial priming results, this pattern suggests that a priming effect following exposure to English PS sentences was not observed for heritage speakers with lower fluency in Spanish than English because the Spanish PS sentences were not exceptionally difficult to process and as a result, exposure to the parallel structure in the preceding English PS prime sentences did not result in a significant reduction of syntactic processing difficulty.

Among late bilinguals, the control group for the present study, syntactic processing for the critical segment (segment 3) of Spanish PS sentences was faster following exposure to English PS sentences
and this effect was not modulated by any of the language experience predictor variables or the cumulative effects of exposure to Spanish PS sentences. As postulated for the heritage speakers, the lack of interaction between the within-trial priming effect and the cumulative effects of repeated exposure to Spanish PS sentences suggests that the within-trial cross-linguistic priming effect reflects the residual activation of abstract syntactic representation rather than implicit learning. However, for late bilinguals who were exposed to English earlier in adulthood and late bilinguals who had been exposed to less English, the within-trial priming effect also persisted into the sentence-final segment (segment 4) although only after repeated exposure to Spanish PS sentences. While this suggests an interaction between the influences of priming from single exposure to English PS sentences and cumulative exposure to Spanish PS sentences, the fact that the within-trial priming effect emerged (rather than disappeared) following repeated exposure to Spanish PS sentences indicates that implicit learning of the processing procedures for Spanish PS sentences does not diminish the facilitative effect of exposure to preposition stranding in English. Like the finding that high Spanish fluency heritage speakers showed the largest effect of cross-linguistic within-trial structural priming, the findings for late bilinguals were similarly unexpected given the hypothesis that syntactic representations or structure building procedures associated with preposition stranding would be most accessible during syntactic processing in Spanish for bilinguals who had acquired English at an earlier age, had been exposed to English for more of their lives, used more English than Spanish, and had higher fluency in English.

Although the within-trial cross-linguistic priming results were overall similar between late bilinguals and high Spanish fluency heritage speakers, the priming effect appeared consistently at the critical segment (segment 3) for late bilinguals while the within-trial priming effects recorded for high Spanish fluency heritage speakers registered only at the sentence-final segment (segment 4). A possible explanation for this difference is that structural priming from exposure to English PS sentences facilitates different aspects of syntactic processing for heritage speakers and late bilinguals. In syntactic processing experiments involving real-time measures of processing such as eye-tracking, ERP, and self-paced reading, it is not uncommon for processing difficulties associated with syntactic ambiguity resolution or a grammatical violation to appear following the point in the sentence where the difficulty is hypothesized to occur (Jegerski, 2014; Mitchell, 2004; Swets, Desmet, Clifton, & Ferreira, 2008; Traxler et al., 2014).
While these delayed effects have typically been interpreted as carryover of the processing effects triggered at the initial point of syntactic processing difficulty, they have sometimes been interpreted as reflecting later stages of comprehension or processing (Jegerski, 2014).

While the priming effect recorded at PS sentence segment 3 (including the RC verb, direct object, and stranded preposition) is likely to reflect facilitation of the syntactic processing involved in completing the filler-gap dependency between the prepositional object and the stranded preposition, facilitated syntactic processing at segment 4 is less straightforwardly interpreted due to the design of the PS stimulus sentences—specifically the fact that segment 4 is also the sentence final segment. As such, RTs recorded at segment 4 are likely to reflect both incremental syntactic processing and other sentence ‘wrap-up effects’ involving higher level integrative and interpretive processes that occur at sentence offset (Hirotani, Frazier, & Rayner, 2006; Just & Carpenter, 1980). While this confound limits speculation regarding the level(s) of syntactic processing at segment 4 that are facilitated by priming from English PS sentences, it may explain the complexity of the significant interactions found at segment 4 for late bilinguals—specifically the seemingly contradictory influence of age of English acquisition and length of exposure to English on the within-trial priming effect. To disentangle the various interactions between the within-trial priming effect, cumulative priming effect, and differences in language exposure, use, and proficiency, future work building on the present study should include an additional sentence segment between the critical segment and sentence-final segment to determine which of the interactions are related to processes involved in sentence wrap-up and which are related to later stages of filler-gap dependency processing.69

ACCEPTABILITY JUDGMENTS

Acceptability judgments are widely accepted as reliable indicators of whether a given syntactic structure conforms to the constraints of an individual’s grammar (Cowart, 1997; Schütze, 2016). From this

69 There is some evidence that heritage speakers may experience slower lexical retrieval for low frequency or late-acquired words in the heritage language (e.g., Hulsen, 2000; Montrul & Foote, 2012), however, this is unlikely to play a role in the delayed priming effects in the present study. Heritage language stimuli consisted of common, high frequency words and overall processing speeds for RC and PS sentences suggest that heritage speakers processed these items faster than the late bilingual controls.
perspective, the acceptability ratings obtained in the present study are informative about the status of preposition stranding in Spanish for heritage speakers and late bilinguals. As a group, late bilinguals gave significantly lower ratings for Spanish PS sentences compared to Spanish PP sentences as did heritage speakers, although heritage speakers gave more variable and overall significantly higher ratings for Spanish PS sentences compared to those given by late bilinguals. While heritage speakers are known to give higher ratings for ungrammatical or anomalous linguistic stimuli compared to monolingual or late bilingual controls (the so-called ‘yes bias’ of heritage speakers) (Benmamoun et al., 2013b; Scontras et al., 2015) a comparison between heritage speakers’ ratings for (ungrammatical) Spanish PS sentences and their comparably lower ratings given for ungrammatical CNP sentences suggests that Spanish preposition stranding and CNP island violations were not equally ungrammatical for heritage speakers.

Rather, the ratings for Spanish PS sentences suggest that preposition stranding may have been perceived as grammatical in Spanish by at least some heritage speakers, specifically those who had higher fluency in English than Spanish and used more English in daily interactions. Among heritage speakers who had higher fluency in Spanish than English and heritage speakers who used more Spanish in daily interactions, their significantly lower ratings for Spanish PS sentences suggests that they perceived preposition stranding in Spanish to be ungrammatical, similar to the late bilinguals. While ratings for Spanish PS sentences were generally very low among late bilinguals, the fact that ratings were significantly higher for late bilinguals who had been exposed to more English suggests that the grammatical constraints of Spanish may change over time following exposure to English.

Another important finding of this analysis was that the ratings for Spanish PS sentences given by late bilinguals (but not heritage speakers) significantly increased with repeated exposure to these sentences. Previous studies have shown that repeated exposure to ungrammatical sentences can lead to higher acceptability ratings over the course of an experiment, dubbed the ‘syntactic satiation effect’ (e.g., Goodall, 2011; Snyder, 2000; see also Luka and Barsalou (2005) for increases in ratings for grammatical sentences following repeated exposure). While syntactic satiation effects are not fully understood, it has been proposed that they may reflect changes in the processability of a given syntactic structure (Snyder, 2000). Following this proposal, the significant increase in Spanish PS sentence ratings following repeated exposure to them may likely reflect the same cumulative priming effect observed for these sentences in
the structural priming experiment, which confirms that even when there are no English stimuli in the experiment, repeated exposure to Spanish PS sentence can facilitate implicit learning of their associated syntactic processing procedures among late bilinguals. Importantly, ratings did not improve for ungrammatical CNP sentences with repeated exposure to them, which suggests that syntactic processing procedures for these sentences cannot be implicitly learned to the same extent as for Spanish PS sentences. Although preposition stranding and CNP island violations are both ungrammatical in Spanish, the difference in syntactic satiation observed here suggests that preposition stranding may occupy a slightly different status in the grammars of the late bilinguals tested in the present study.

If this is the case, however, then the question remains as to why the cumulative priming effect was consistent across all late bilinguals in the acceptability judgment experiment but was only found for late bilinguals with the ‘strongest’ Spanish in the priming experiment. It is likely that differences in statistical power and sensitivity to cumulative priming effects between the RTs measure used in the self-paced listening task and the Likert scale measure used in the acceptability rating task play a role, but this conclusion remains speculative pending further investigation.

Lastly, one final result of the acceptability ratings analysis that does not bear directly on the question of cross-linguistic influence on syntactic processing is worth mentioning: Both late bilinguals and heritage speakers who had higher fluency in Spanish than English showed the largest decrease in average ratings over PP and PS sentences following repeated exposure to them. Given the lack of interaction with COND (grammatical vs. ungrammatical) for heritage speakers or late bilinguals, it seems that the decrease in ratings was not significantly different for Spanish PS and PP sentences, but it is not clear why overall ratings should have decreased in both groups.

**BILINGUAL SYNTACTIC INTEGRATION**

The late bilinguals who were tested in the present study were not expected to show within-trial cross-linguistic priming effects for Spanish PS sentences. Although the research on cross-linguistic structural priming is still fairly limited, the main findings from this line of inquiry have been interpreted as evidence that structures that are found in both of a bilingual’s languages and exhibit similar surface word order (e.g., the passive structure in Spanish and English) may share a single underlying syntactic representation or set of processing procedures (Bernolet et al., 2007, 2013; Carando, 2015; Hartsuiker &
Berollet, 2017; Hartsuiker et al., 2004; Loebell & Bock, 2003). With these shared structures, cross-linguistic structural priming occurs when processing a sentence that exhibits the structure in one language increases its activation level (or reinforces the associated syntactic processing routines) and as a result its subsequent availability during syntactic processing in the other language. Given that preposition stranding is not a structure that is shared between English and Spanish, syntactic processing of English PS sentences was not expected to affect processing of Spanish PS sentences.

Although late bilinguals were included in the present study a control group, the finding that exposure to preposition stranding in English facilitated syntactic processing for (illicit) preposition stranding in Spanish among late Spanish-English bilinguals is significant for current theories of bilingual language integration at the level of syntax. The finding that within-trial cross-linguistic priming effects observed for late bilinguals in the present study did not significantly change with repeated exposure to Spanish PS sentences suggests that these effects were rooted in the residual activation of syntactic representations associated with preposition stranding (rather than implicitly learning to process these structures during the experiment). This finding fits with Hartsuiker et al.’s (2004) model of bilingual syntactic integration with one modification: removal of the stipulation that a combinatorial node is only shared by lexical items across a bilingual’s languages when the structure specified by the combinatorial node exists in both languages. The indication that late bilinguals tested in the present study were able to access abstract syntactic representations that are a priori specific to English during Spanish syntactic processing suggests that Hartsuiker et al.’s model must be extended to allow lexical items in one of a bilingual’s languages (e.g., Spanish) to also link to combinatorial nodes that are a priori specific to a bilingual’s other language (e.g., English).

The finding that late bilinguals who had the strongest Spanish also showed evidence of implicitly learning to process the Spanish PS sentences (via the significant cumulative priming effect) is perhaps less surprising given previous work that has shown that monolingual English speakers readily adapt to comprehend unfamiliar syntactic structures (the needs construction) (Fraundorf & Jaeger, 2016; Kaschak & Glenberg, 2004). What’s more surprising is that cumulative priming for Spanish PS sentences was not found for all late bilinguals. As stated above, the late bilinguals who showed a cumulative priming effect for Spanish PS sentences were also likely to have had the least exposure to preposition stranding in
English and the reason for the cumulative priming effect could be that repeated exposure to Spanish PS sentences had a larger effect on implicitly learning to process preposition stranding in Spanish for these individuals compared to late bilinguals who likely had more exposure to preposition stranding in English. While this explanation is speculative, it does align with the Tuning Hypothesis of syntactic processing in which processing preferences change over time to match structural patterns in the language input (Cuetos et al., 1996).

Late bilinguals who had more exposure to English likely had more experience with sentences involving a relativized prepositional object denoting an instrument or location in which the preposition appeared (stranded) in its base position in the relative clause. Following the Tuning Hypothesis, upon encountering the first NP in the Spanish PS sentences, which was either an instrumental or locative prepositional object, these late bilinguals may have been more likely to expect the preposition to appear in its base position in the relative clause (rather than in the pied-piped position, at the onset of the RC), which would facilitate syntactic processing of these sentences from the start of the experiment. This same account would also explain why heritage speakers, who have had the most exposure to English, did not show any indication of cumulative priming effects for Spanish PS sentences. In one of the few other studies to examine L2-on-L1 influence during online syntactic processing, Dussias and Sagarra (2007) similarly suggested that the differences in Spanish RC attachment preferences they observed between late Spanish-English bilinguals who were living in an English-speaking environment at the time of testing vs. those living in a Spanish-speaking environment could only be explained by allowing the L1 parser to be sensitive to the statistical frequency of RC structures in the environment.

**HERITAGE SPEAKER DIFFERENCES**

The main objective of the present study was to determine whether dominant language influence during heritage language online processing could explain some of the common findings reported in heritage language studies that have been largely attributed to differences in grammatical representation. It is important to recall at this point that the present study was designed to serve as a test case for the hypothesis that influence from the dominant language during real time heritage language processing could account for some of the divergence and instability that are often reported in heritage speaker studies that utilize offline experimental methods. Although most divergence from baseline that has been
documented for heritage speakers has been in the domain of morphosyntax, the present study tested cross-linguistic influence on real-time processing at the level of core syntax for two reasons. The first reason is that a few heritage language studies have reported evidence of instability or variation among heritage speakers in aspects of core syntax (Cuza, 2013; Montrul et al., 2008b; Pascual y Cabo & Soler, 2015), and as a direct test of influence from the dominant language on heritage language syntactic processing, the findings of the present study bear directly on the conclusions drawn in this prior work.

The second reason is one of methodological practicality. Showing direct evidence of dominant language influence during heritage language morphosyntactic processing would have a much larger impact in heritage language research given that this is the language domain that has received the most attention in this literature. However, testing cross-linguistic influence on heritage language processing at the level of morphosyntax is less easily accomplished since there is no established experimental paradigm for testing cross-linguistic influence on morphosyntactic processing. In contrast, although use of the structural priming paradigm with bilinguals is relatively new, this method has been successfully used in a number of studies to measure cross-linguistic influence at the level of syntax and there is sufficient empirical work in this area to guide interpretation of the results of the present study. Even if an experimental paradigm for testing cross-linguistic influence on morphosyntactic processing could be developed, the lack of prior research with this method would severely limit the interpretation of the current results.

Given the experimental design, the findings of the present study cannot be taken as direct evidence that influence from the dominant language during processing is in fact responsible for divergence and instability in other areas of heritage language grammar. Rather, the findings reported here can only be taken as an indication of the extent to which heritage speakers can and do access syntactic representations and syntactic processing procedures that are a priori specific to their dominant language when comprehending sentences in their heritage language. Since core syntax has often been described as the linguistic domain that is most resistant to cross-linguistic influence, the findings of dominant language influence on heritage language syntactic processing in the present study strongly suggests that other heritage language domains are susceptible to the same kind of real-time influence from the dominant language during processing.
The key finding that within-trial cross-linguistic priming effects observed for high Spanish fluency heritage speakers in the present study did not significantly change with repeated exposure to Spanish PS sentences suggests that these effects were rooted in the residual activation of syntactic representations associated with preposition stranding (rather than implicitly learning to process these structures during the experiment). As noted above, this finding is consonant with Hartsuiker et al.’s (2004) model of bilingual syntactic integration with the modification to the model that combinatorial nodes encoding syntactic configurations that are a priori specific to the dominant language can also link to lexical items in the heritage language. While Hartsuiker et al.’s (2004) model was designed to account for cross-linguistic influence at the level of syntax, the consistency of the of the present study’s findings with this model provides indirect support for the conceptually similar mechanism driving cross-linguistic influence at the level of heritage language morphology put forth by Putnam and Sánchez (2013).

To date, the model described in Putnam and Sánchez (2013) is one of the few models that has been offered to explain the divergence and instability in heritage speakers’ linguistic behavior. This model was proposed in the generativist framework and is based on the assumptions that grammatical properties of a given lexical item are encoded in its formal features and that the activation level of a given FF value is determined by the frequency of exposure to lexical items that instantiate the FF value. Following these assumptions, cross-linguistic influence is the result of FF values from the dominant language becoming associated with lexical items in the heritage language. In this account, heritage language properties that show instability or divergence from baseline measures are the result of moment-to-moment fluctuations in the activation levels between heritage language lexical items and their competing (dominant vs. heritage language) FF values. As heritage speakers process more input in the dominant language and less input in the heritage language, FF values that are specific to the dominant language become more strongly linked to heritage language lexical items and these dominant language feature values may eventually replace the heritage language FF values altogether.

Generalizing over differences in the theoretical underpinnings of Putnam and Sánchez’s (generativist) and Hartsuiker et al.’s (lexicalist) models, the mechanism of cross-linguistic influence in both models—changing activation levels between lexical items in one language and grammatical or structural properties of the other language—is conceptually identical. Both models assume that syntax is encoded
in lexical entries and that exposure to language input in which particular syntactic features are instantiated strengthens the activation level of those syntactic features in the lexicon (FF values and combinatorial nodes). Crucially, the activation level for a given syntactic feature is linked to the frequency with which it is encountered in the language input, which can explain fluctuations in the activation of grammatical properties or what appears on the surface to be variation and instability in heritage language linguistic competence.

Putnam and Sánchez (2013) also note that the strength of activation between dominant language FFs and heritage language lexical items may parallel changes in proficiency levels in the dominant language. The findings of the present study are also in line with this claim. While within-trial cross-linguistic priming effects were absent among heritage speakers with the highest fluency in English compared to Spanish, the overall faster processing times and higher ratings for Spanish PS sentences among these individuals suggests that they experienced little difficulty accessing the syntactic representations associated with preposition stranding during Spanish syntactic processing. The finding that relative fluency between Spanish and English was the most consistent variable influencing heritage speaker performance across all measures in the present study is consistent with other work in bilingual processing that has found language proficiency to be a significant predictor of performance (Dussias et al., 2015; Moreno & Kutas, 2005; Schwieter, 2007) and cross-linguistic influence on processing (Blumenfeld & Marian, 2013; Weber & Cutler, 2004), as well as performance on experimental measures among heritage speakers (Montrul, 2009; Montrul et al., 2008a; but see Cuza & Frank, 2011).

The finding that age of English acquisition, length of exposure to English, and current use of Spanish were less consistent in their influence across experimental measures for heritage speakers suggests that overall relative proficiency in the heritage and dominant language are more important in determining aspects of heritage language syntactic processing than differences in dominant language exposure and heritage language use per se (see also Abutalebi, Cappa, & Perani, 2001). Although it has been suggested that divergence and instability in heritage languages stems from reduced heritage language input early in life (Bolger & Zapata, 2011; Montrul, 2008; Montrul & Bowles, 2009; Pascual y Cabo & Soler, 2015) and more limited opportunities to use the heritage language later in life (Montrul, 2008; Polinsky, 2011; Rothman, 2009; see also Cuza & Frank, 2011; Martohardjono et al., 2017; Oh &
the findings of the present study suggest that these differences are less important than relative differences in heritage language and dominant language proficiency for the heritage speakers tested here.\textsuperscript{70}

\textbf{LIMITATIONS AND FUTURE DIRECTIONS}

While the present study was successful in producing novel measurements of baseline syntactic processing for grammatical L1 structures and L2 influence on processing of ungrammatical L1 structures for heritage Spanish speakers and late Spanish-English bilinguals, the design of the experiments limited what could be inferred from the results of each analysis. Regarding L1 baseline syntactic processing, the results of the present study showed that syntactic processing was qualitatively identical for heritage speakers and late bilinguals, with a slight quantitative edge for heritage speakers. While the similarity between groups generally aligns with the limited research on heritage language syntactic processing, the inclusion of a set of syntactic structures that are grammatical in Spanish but not English would have provided a nice baseline for comparison to see if heritage speakers and late bilinguals still pattern the same for processing Spanish sentences that do not have structurally parallel English equivalents compared to syntactic processing of structures that are the shared in Spanish and English (object RC sentences) and structures that are grammatical in English but not Spanish (PS sentences).

One possible explanation for the finding in the baseline processing results, that heritage speakers were faster to process grammatical RC sentence compared to late bilinguals, is that the constant switching between English and Spanish in the cross-linguistic priming task may have created a higher barrier for switching from English to Spanish for late bilinguals than heritage speakers. Although switching between English and Spanish is not qualitatively dissimilar to what bilinguals may experience in everyday life, the frequency of switching throughout the task may have advantaged heritage speakers, who have generally had more experience in a bilingual environment. Even though an experiment that included only Spanish sentences would be unlikely to put heritage speakers or late bilinguals in a purely ‘monolingual mode’ (Grosjean, 1998), an experiment that did not require subjects to switch into English every 1–3

\textsuperscript{70} See also Bayram (2013) and Putnam and Sánchez (2013) for further discussion of potential issues with attributing heritage language differences to estimations of reduced input.
sentences may level the playing field between these two groups and produce different L1 syntactic processing signatures for heritage speakers and late bilinguals.

Regarding the effects of within-trial cross-linguistic priming and between trial (within-language) cumulative priming for Spanish PS sentences found in the present study, more research on heritage language syntactic processing is needed to more fully interpret these findings. Specifically, given the complex (and the few contradictory) interactions involving cumulative priming for late bilinguals, future work will need to tease apart how differences in language exposure, use, and proficiency interact with the cumulative priming effects and whether these effects can be attributed to implicit learning of the syntactic processing associated with Spanish PS sentences or sensitivity to the probability of encountering this structure during the experiment, or both.

One limitation of the current study is that the mixed-effects models generated in the priming analyses did not include any interaction terms between the language experience predictors. While this makes some of the interactions involving the language experience variables difficult to interpret in some cases, this was intentional for two reasons: First, interactions involving more than three terms are very difficult to interpret. Second, with the current number of subjects in each group, the increase in the number of fixed-effects interactions that would follow from allowing interactions between cumulative priming, within-trial priming, and each of the four language experience predictor variables would lead to model overfitting. For linear-mixed effects models, the rule of thumb is that at least 20 observations are required for each effect and interaction, including both fixed and random effects. With fewer than this number of observations, there is not enough data for the model to fit all of the effects and interactions. To better understand how the language experience variables analyzed in the present study interact to influence bilingual syntactic processing and cross-linguistic influence, future work will need to test a larger sample of bilinguals to obtain sufficient data and this work would also benefit from more restricted enrollment criteria for heritage speakers and late bilinguals. In this way, one or two of the language experience variables tested in the present study could be controlled more tightly while allowing variation in the other predictors, which would help to clarify some of the results obtained here.

Similarly, the interpretations of the cross-linguistic priming and cumulative priming effects for (ungrammatical) Spanish PS sentences are limited without additional baseline measures of cross-
linguistic and cumulative priming. To increase the interpretability of the cross-linguistic priming effects obtained in the present study, future work would benefit from also measuring cross-linguistic priming for a structure that is grammatical in both languages to obtain a baseline measure of sensitivity to cross-linguistic priming among the bilingual subjects. This would address the first possible explanation for the absence of priming effects among heritage speakers who had higher fluency in English. For these speakers, the lack of cross-linguistic priming effects was interpreted as an indication that the Spanish PS sentences were already easy enough to process that within-trial priming from English PS sentences did not further facilitate processing. To verify this interpretation, heritage speakers and late bilinguals should be tested on within-trial cross-linguistic priming during comprehension for a structure that is a priori difficult to process but grammatical in both Spanish and English. For these sentences, if the results showed no priming effects for heritage speakers with similar characteristics, this would suggest that these individuals are perhaps not sensitive to cross-linguistic priming. On the other hand, if these results show within-trial cross-linguistic priming effects, this would confirm the current interpretation that heritage speakers are sensitive to within-trial cross-linguistic priming but this effect does not further facilitate syntactic processing of the Spanish PS structures that are already easy to process.

Relatedly, to increase the interpretability of the results suggesting a cumulative priming effect, future work would also benefit from testing cumulative priming of a syntactic structure that is novel in both languages (similar to the needs construction tested in Fraundorf and Jaeger (2016) and Kaschak and Glenberg (2004)) to obtain a baseline measure of cumulative priming for a novel grammatical structure. This result would help clarify the lack of any cumulative priming effects for Spanish PS sentences among heritage speakers.

Lastly, given that the cross-linguistic priming findings in the present study were more compatible with the cross-linguistic structural priming account based on residual activation of shared syntactic representations (rather than the implicit learning account), future work should replicate the present study with an experimental condition that varies the use of translation equivalents between English prime and Spanish target PS sentences. If the cross-linguistic priming results in the present study are due to residual activation of the syntactic representations associated with preposition stranding, then there should be differences in the priming effect size based on whether or not translation equivalents are used.
between prime and target sentences, in line with previous findings related to cross-linguistic lexical boost effects.

CONCLUSIONS

The present study was conducted to determine whether cross-linguistic influence from heritage speakers’ dominant language during heritage language online processing could explain some aspects of divergence and instability that have been widely reported in the heritage language literature. To address this question, a cross-linguistic structural priming experiment was conducted with a group of heritage Spanish speakers and late Spanish-English bilinguals to test whether exposure to preposition stranding in English—a feature of core syntax that does not exist in any variety of Spanish—could facilitate processing of (ungrammatical) preposition stranding in a subsequently encountered Spanish sentence. The first hypothesis was that exposure to preposition stranding in English would have an immediate effect of facilitating syntactic processing of ungrammatical preposition stranding in Spanish sentences among heritage speakers but not late bilinguals. The second hypothesis was that the magnitude of the priming effect would be greater for heritage speakers who acquired English earlier in life, had been immersed in an English-speaking environment for longer, regularly used more English than Spanish, and were more proficient in English than Spanish.

The findings of the present study show that, contrary to expectations, heritage speakers who acquired English earlier in life, had been immersed in English for longer, used more English in daily interactions, and had higher proficiency in English than Spanish did not show a significant effect of cross-linguistic priming, while heritage speakers who had higher fluency in Spanish than English and all late bilinguals did show a significant priming effect. Importantly, the same heritage speakers who did not show the cross-linguistic priming effect also processed preposition stranding in Spanish faster and gave higher acceptability ratings for these sentences, suggesting that preposition stranding in Spanish may not be entirely ungrammatical for these individuals.

Among late bilinguals and the heritage speakers who did show a within-trial cross-linguistic priming effect, the lack of interaction between this effect and cumulative exposure to preposition stranding in the Spanish target sentences suggest that facilitated syntactic processing of preposition stranding in Spanish following exposure to preposition stranding in English resulted from residual activation of the
abstract syntactic representations associated with preposition stranding, rather than implicitly learning process these sentences during the experiment. At the same time, late bilinguals who had the strongest Spanish at the time of testing also showed cumulative priming effects, which suggests that these individuals also implicitly learned processing procedures for preposition stranding in Spanish during the experiment.

Together, these results provide some of the first evidence that L1 core syntactic processing is susceptible to L2 influence for simultaneous and early sequential bilinguals as well as for late bilinguals. Following the standard assumption that core syntax is the most resistant language domain to cross-linguistic influence, the findings of the present study suggest that all domains of language are likely susceptible to the same cross-linguistic influence during online processing. While the present findings suggest that cross-linguistic influence on processing is a viable explanation for the divergence and instability that is commonly observed among heritage speakers using offline measures, it is important to mention that each of the explanations that have been given heritage language divergence, including arrested development and attrition of grammatical knowledge, are not mutually exclusive. It is more likely the case that each plays a role to differing degrees depending on the linguistic structures and the particular circumstances of heritage language acquisition and use.

Research on cross-linguistic influence has recently begun to explore the role that knowledge of a second language plays during processing of the first-learned language. This work has shown that where processing routines differ between a bilingual’s L1 and L2, immersion in an L2 environment can shift L1 processing routines towards those of the L2 (Dussias, 2004; Dussias & Sagarra, 2007; Martohardjono et al., 2017). So far, the limited work in this domain has shown this influence for processing structural ambiguities that are found in both L1 and L2. The present study contributes to this growing area of research by showing for the first time that processing of L1 core syntax can also be influenced to a similar degree by acquisition of a second language. The growing evidence suggests that cross-linguistic structural priming may play a potentially important role in driving contact-induced language change (Fernández, Souza, & Carando, 2017; Kootstra & Doedens, 2016). While the available evidence shows that priming from a later-learned language can subtly shape the first-learned language by increasing the frequency with which bilinguals produce syntactically licit but dispreferred L1 structures (Carando, 2015).
and by extending licit L1 structures to new L1 environments (Torres Cacoullos & Travis, 2011), little is known about whether cross-linguistic priming can shift L1 core syntactic processing routines. The present study addresses this gap by showing that core L1 syntactic processing routines are also susceptible to priming from exposure to L2.

The adaptation of a cross-linguistic structural priming comprehension paradigm in the present study underscores the potential of this method to illuminate aspects of bilinguals syntactic processing that have until now received little attention due to a lack of adequate experimental measures. Although cross-linguistic structural priming is not in itself a novel method, it has very rarely been implemented with language comprehension tasks (but see Kidd, Tennant, & Nitschke, 2015; Weber & Indefrey, 2009). One potential reason for this may be the difficulty of selecting experimental measures that are both sensitive to cross-linguistic priming and appropriate for bilinguals, given their varied experience in each language (Grosjean, 2016). The present findings suggest that self-paced listening is sensitive to cross-linguistic structural priming effects and is a suitable measure for testing hypothesis related to cross-linguistic influence on processing with bilinguals who have not completed equivalent schooling and literacy training in both languages. Lastly, the use of a comprehension task to measure the effects of structural priming skirts potential issues related to subjects’ avoidance of producing certain grammatical structures for reasons that are external to the grammar, such as self-monitoring. By pairing cross-linguistic structural priming with an appropriately-designed language comprehension task, this method can be successfully used to probe new aspects of cross-linguistic influence on processing, including testing how bilinguals adapt to novel grammatical structures.
APPENDICES

APPENDIX A: SCRIPT FOR LANGUAGE BACKGROUND SCREENER

I’d like to ask you a few questions to make sure that you meet the basic criteria for inclusion in this study. Your responses to these questions will remain confidential and provide the basis for inclusion in this study. You may decline to respond to any of these questions, but please note that consideration for participation in this study is contingent upon answering each of these questions.

1. Where were you born?

2. If born abroad, at what age did you arrive in the US?

3. How old are you?

4. What is the highest level of formal schooling you have completed?

5. Do you live alone, or with a significant other?

5a. If you live with a significant other, what country was he/she born in?

5b. If you live with a significant other, at what age did he/she arrive in the US?

5c. If you live with a significant other, how old is he/she?

5d. If you live with a significant other, what is the highest level of formal schooling he/she has completed?

6. What language(s) do you speak at home?

7. Who were your primary caregiver(s) from birth to age 10?

7a. What country were your primary caregiver(s) born in? (list one country for each primary caregiver)

7b. If your primary caregiver(s) were born abroad, how old were they when they arrived in the US?

7c. If your primary caregiver(s) were born abroad, what year did they arrive in the US?

8. What language did you speak with your primary caregiver(s) from birth to age 10?

9. How well do you understand Spanish? (choose one of the following)

I understand…

1 = little to nothing of what I hear
2 = some of what I hear
3 = about half of what I hear
4 = most of what I hear
5 = everything I hear
## APPENDIX B: PRIMING EXPERIMENT CON/WITH TRIAL SENTENCES

<table>
<thead>
<tr>
<th>No.</th>
<th>Target</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Este es el bate que José rompió la lámpara con cuando se enojó.</td>
<td>“This is the bat that José broke the lamp with when he got angry.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>This is the rock that Alice broke the window with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>This is the window that Alice broke with the rock.</td>
</tr>
<tr>
<td>2</td>
<td>Este es el cemento que Marta construyó el patio con después de comprar la casa.</td>
<td>“This is the cement that Marta built the patio with after buying the house.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>This is the wood that Robert built the wall with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>This is the wall that Robert built with the wood.</td>
</tr>
<tr>
<td>3</td>
<td>Esta es la esponja que Manuel limpió la mesa con después de la fiesta.</td>
<td>“This is the sponge that Manuel cleaned the table with after the party.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>This is the rag that Bill cleaned the floor with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>This is the floor that Bill cleaned with the rag.</td>
</tr>
<tr>
<td>4</td>
<td>Esta es la manta que Sara tapó el sillón con cuando hacía frío.</td>
<td>“This is the blanket that Sarah covered the chair with when it was cold.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>This is the plastic that Mary covered the window with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>This is the window that Mary covered with the plastic.</td>
</tr>
<tr>
<td>5</td>
<td>Este es el zapato que Pedro aplastó la hormiga con cuando estaba aburrido.</td>
<td>“This is the shoe that Pedro crushed the ant with when we was bored.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>This is the brick that John crushed the can with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>This is the can that John crushed with the brick.</td>
</tr>
<tr>
<td>6</td>
<td>Este es el serrucho que Eduardo cortó la rama con para hacer leña.</td>
<td>“This is the saw that Eduardo cut the branch with to make firewood.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>These are the scissors that David cut the paper with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>This is the paper that David cut with the scissors.</td>
</tr>
<tr>
<td>7</td>
<td>Estas son las fotos que Ana decoró la pared con antes de la fiesta.</td>
<td>“These are the photos that Ana decorated the wall with before the party.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>These are the candles that Robert decorated the cake with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>This is the cake that Robert decorated with the candles.</td>
</tr>
<tr>
<td>8</td>
<td>Este es el lápiz que Sara dibujó la imagen con para su clase de arte.</td>
<td>“This is the pencil that Sarah drew the image with for her art class.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>This is the marker that Christen drew the portrait with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>This is the portrait that Christen drew with the marker.</td>
</tr>
<tr>
<td>9</td>
<td>Esta es la cinta que Carlos arregló el cartel con cuando se rompió.</td>
<td>“This is the tape that Carlos fixed the poster with when it ripped.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>This is the glue that Jen fixed the vase with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>This is the vase that Jen fixed with the glue.</td>
</tr>
<tr>
<td>10</td>
<td>Este es el microondas que Carlos calentó la sopa con antes de cenar.</td>
<td>“This is the microwave that Carlos heated the soup with before dinner.”</td>
</tr>
<tr>
<td></td>
<td>Prime</td>
<td>This is the pot that Christopher heated the water with.</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td></td>
</tr>
</tbody>
</table>
11 Control This is the water that Christopher heated with the pot.
11 Target Este es el hacha que Daniel golpeó el árbol con para cortarlo.
   “This is the axe that Daniel hit the tree with to cut it.”
11 Prime This is the hammer that Thomas hit the nail with.
11 Control This is the nail that Thomas hit with the hammer.

12 Target Esta es la trampa que Santiago mató la rata con cuando estaba en su casa.
   “This is the trap that Santiago killed the rat with when it was in his house.”
12 Prime This is the poison that Daryl killed the bugs with.
12 Control These are the bugs that Daryl killed with the poison.

13 Target Esta es la lechuga que Luis hizo la ensalada con para la cena.
   “This is the lettuce that Luiz made the salad with for dinner.”
13 Prime This is the clay that Janet made the pitcher with.
13 Control This is the pitcher that Janet made with the clay.

14 Target Esta es la taza que Enrique midió la harina con cuando horneó el pan.
   “This is the cup that Enrique measured the flour with when he baked bread.”
14 Prime This is the ruler that William measured the fabric with.
14 Control This is the fabric that William measured with the ruler.

15 Target Esta es la sal que Carlos derritió el hielo con después de quitar la nieve.
   “This is the salt that Carlos melted the ice with after removing the snow.”
15 Prime This is the lighter that Theresa melted the wax with.
15 Control This is the wax that Theresa melted with the lighter.

16 Target Este es el palo que Marta mezcló la pintura con antes de pintar la pared.
   “This is the stick that Marta mixed the paint with before painting the wall.”
16 Prime This is the spoon that Carl mixed the dough with.
16 Control This is the dough that Carl mixed with the spoon.

17 Target Esta es la clave que Ana abrió la puerta con cuando perdió su llave.
   “This is code that Ana opened the door with when she lost her key.”
17 Prime This is the knife that Matthew opened the box with.
17 Control This is the box that Matthew opened with the knife.

18 Target Este es el jabón que Luis removió la mancha con antes de lavar la prenda.
   “This is the soap that Luis removed the stain with before washing the garment.”
18 Prime These are the tweezers that Amanda removed the thorn with.
18 Control This is the thorn that Amanda removed with the tweezers.

19 Target Este es el telescopio que Carmen vio el planeta con cuando miraba las estrellas.
   “This is the telescope that Carmen saw the planet with when she was looking at the stars.”
19 Prime These are the binoculars that Anthony saw the bird with.
19 Control This is the bird that Anthony saw with the binoculars.

20 Target Esta es la llave que Pedro rayó el carro con cuando estaba enojado.
   “This is the key that Pedro scratched the car with when he was mad.”
Prime  This is the toy that Eric scratched the floor with.
Control  This is the floor that Eric scratched with the toy.

21 Target  Este es el cuchillo que Luis amenazó el vecino con después de la pelea.
"This is the knife that Luis threatened the neighbor with after the fight."
Prime  This is the gun that Brian threatened the witness with.
Control  This is the witness that Brian threatened with the gun.

22 Target  Esta es la cuerda que Carlos amarró el paquete con antes de enviarlo.
"This is the cord that Carlos tied up the package with before sending it."
Prime  This is the rope that Denise tied the branches with.
Control  These are the branches that Denise tied with the rope.

23 Target  Este es el detergente que Miguel lavó la ropa con para quitar las manchas.
"This is the detergent that Miguel washed the clothing with to remove the stains."
Prime  This is the shampoo that Charles washed the dog with.
Control  This is the dog that Charles washed with the shampoo.

24 Target  Esta es la pluma que Isabel escribió la carta con antes de irse.
"This is the pen that Isabel wrote the letter with before leaving."
Prime  This is the pencil that David wrote the message with.
Control  This is the message that David wrote with the pencil.
APPENDIX C: PRIMING EXPERIMENT EN/IN TRIAL SENTENCES

1 Target  Esta es la tienda que Gonzalo compró el pollo en para cocinar la cena.  
"This is the store that Gonzalo bought the chicken in to cook dinner."
Prime  This is the flowershop that David bought the plant in.
Control  This is the plant that David bought in the flowershop.

2 Target  Esta es la maleta que Pedro trajo la ropa en cuando se fue de vacaciones.  
"This is the suitcase that Pedro brought the clothing in when he went on vacation."
Prime  This is the bag that Donna brought the gift in.
Control  This is the gift that Donna brought in the bag.

3 Target  Esta es la playa que Andrés enterró el tesoro en cuando escapó de la isla.  
"This is the beach that Andrés buried the treasure in when he escaped from the island."
Prime  This is the field that Elizabeth buried the evidence in.
Control  This is the evidence that Elizabeth buried in the field.

4 Target  Este es el pozo que Ana quemó la basura en después de limpiar el jardín.  
"This is the pit that Ana burned the trash in after cleaning the garden."
Prime  This is the trash can that Frank burned the leaves in.
Control  These are the leaves that Frank burned in the trash can.

5 Target  Esta es la trampa que Carlos atrapó la rata en para sacarla de su casa.  
"This is the trap that Carlos caught the rat in to get it out of his house."
Prime  This is the net that Charles caught the insect in.
Control  This is the insect that Charles caught in the net.

6 Target  Este es el gimnasio que Daniel hizo los ejercicios en antes del torneo.  
"This is the gym that Daniel did the exercises in before the tournament."
Prime  This is the hotel that Jason did the interview in.
Control  This is the interview that Jason did in the hotel.

7 Target  Este es el cuarto que Isabel descubrió la pista en después del asesinato.  
"This is the room that Isabel discovered the clue in after the murder."
Prime  This is the cave that Jennifer discovered the bones in.
Control  These are the bones that Jennifer discovered in the cave.

8 Target  Este es el establo que Enrique examinó el caballo en cuando se enfermó.  
"This is the stable that Enrique examined the horse in when it got sick."
Prime  This is the garage that Mark examined the car in.
Control  This is the car that Mark examined in the garage.

9 Target  Este es el cajón que José encontró la llave en cuando la perdió.  
"This is the drawer that José found the key in when he lost it."
Prime  This is the box that Joseph found the photo in.
Control  This is the photo that Joseph found in the box.

10 Target  Esta es la clase que Luis dio el discurso en para su proyecto final.  
"This is the class that Luis gave the speech in for his final project."
Prime  This is the court that Diana gave the argument in.
Control  This is the argument that Diana gave in the court.

11 Target  Este es el jardín que Martín cultivó la calabaza en antes de la sequía.
"This is the garden that Martin grew the squash in before the drought."
Prime  This is the pot that Kevin grew the plant in.
Control  This is the plant that Kevin grew in the pot.

12 Target  Este es el pasillo que Gonzalo escuchó el ratón en cuando llegó a casa.
"This is the hallway that Gonzalo heard the mouse in when he got home."
Prime  This is the room that Martha heard the noise in.
Control  This is the noise that Martha heard in the room.

13 Target  Esta es la carpeta que María escondió la carta en para mantenerla segura.
"This is the folder that Maria hid the letter in to keep it safe."
Prime  This is the closet that Linda hid the gift in.
Control  This is the gift that Linda hid in the closet.

14 Target  Esta es la fábrica que Miguel inventó la máquina en antes de su promoción.
"This is the factory that Miguel invented the machine in before his promotion."
Prime  This is the laboratory that Maria invented the formula in.
Control  This is the formula that Maria invented in the lab.

15 Target  Esta es la plaza que Santiago perdió su celular en después del concierto.
"This is the square that Santiago lost his cell phone in after the concert."
Prime  This is the park that Frank lost the camera in.
Control  This is the camera that Frank lost in the park.

16 Target  Este es el hotel que Carlos conoció el hombre en antes de la reunión.
"This is the hotel that Carlos met the man in before the meeting."
Prime  This is the coffee shop that Elizabeth met the actor in.
Control  This is the actor that Elizabeth met in the coffee shop.

17 Target  Este es el bosque que Isabel vio el oso en después de su caminata.
"This is the forest that Isabel saw the bear in after her hike."
Prime  This is the theater that Michelle saw the movie in.
Control  This is the movie that Michelle saw in the theater.

18 Target  Este es el banco que Pedro firmó el documento en antes de sacar el dinero.
"This is the bank that Pedro signed the document in before withdrawing the money."
Prime  This is the office that Patricia signed the contract in.
Control  This is the contract that Patricia signed in the office.

19 Target  Este es el aula que Miguel derramó el jugo en cuando se deslizó.
"This is the classroom that Miguel spilled the juice in when he slipped."
Prime  This is the bathroom that Rebecca spilled the cleaner in.
Control  This is the cleaner that Rebecca spilled in the bathroom.

20 Target  Este es el gimnasio que Julieta entrenó el equipo en antes del campeonato.
"This is the gym that Julieta trained the team in before the championship."
Prime: This is the school that Sarah trained the officers in.
Control: These are the officers that Sarah trained in the school.

21 Target: Este es el estadio que Martín ganó el campeonato en cuando jugaba fútbol.
“This is the stadium that Martín won the championship in when he played soccer.”
Prime: This is the raffle that Stephanie won the prize in.
Control: This is the prize that Stephanie won in the raffle.

22 Target: Este es el estudio que Luis escribió la canción en antes de ser famoso.
“This is the studio that Luis wrote the song in before he was famous.”
Prime: This is the cabin that Jennifer wrote the book in.
Control: This is the book that Jennifer wrote in the cabin.
APPENDIX D: PRIMING EXPERIMENT SPANISH RC SENTENCES

1. *Estas son las camisas que Sofia regaló a la iglesia el año pasado.*
   "These are the shirts that Sofia donated to the church last year."

2. *Este es el teléfono que Camila usó para llamar la policía anoche.*
   "This is the telephone that Camila used to call the police last night."

3. *Este es el cuarto dónde Sara puso su oficina cuando se mudó.*
   "This is the room where Sara put her office when she moved."

4. *Esta es la clave que Carlos usó para hackear la computadora ayer.*
   "This is the code that Carlos used to hack the computer yesterday."

5. *Este es el aeropuerto dónde Juan perdió su equipaje hace unos cuantos meses.*
   "This is the airport where Juan lost his luggage a few months ago."

   "This is the street where Pedro crashed his car during the storm."

7. *Este es el barrio dónde Mariana compró su casa hace diez años.*
   "This is the neighborhood where Mariana bought her house 10 years ago."

8. *Esta es la película que Eric ve cuando esta triste.*
   "This is the movie that Eric watches when he is sad."

9. *Este es el anillo que Martina le regaló a su amiga para su cumpleaños.*
   "This is the ring that Martina gifted to her friend for her birthday."

10. *Esta es la revista que Daniela lee todas las noches.*
    "This is the magazine that Daniela reads every night."
APPENDIX E: ACCEPTABILITY JUDGMENT EXPERIMENT CON “WITH” SENTENCES

1 Gramm.  
**Este es el bate con que José rompió la lámpara cuando se enojó.**  
“This is the bat with which José broke the lamp when he got angry.”  
Ungramm.  
**Este es el bate que José rompió la lámpara con cuando se enojó.**  
“This is the bat that José broke the lamp with when he got angry.”

2 Gramm.  
**Este es el cemento con que Marta construyó el patio después de comprar la casa.**  
“This is the cement with which Marta built the patio after buying the house.”  
Ungramm.  
**Este es el cemento que Marta construyó el patio con después de comprar la casa.**  
“This is the cement that Marta built the patio with after buying the house.”

3 Gramm.  
**Esta es la esponja con que Manuel limpió la mesa después de la fiesta.**  
“This is the sponge with which Manuel cleaned the table after the party.”  
Ungramm.  
**Esta es la esponja que Manuel limpió la mesa con después de la fiesta.**  
“This is the sponge that Manuel cleaned the table with after the party.”

4 Gramm.  
**Esta es la manta con que Sarah tapó el sillón cuando hacía frío.**  
“This is the blanket with which Sarah covered the chair when it was cold.”  
Ungramm.  
**Esta es la manta que Sarah tapó el sillón con cuando hacía frío.**  
“This is the blanket that Sarah covered the chair with when it was cold.”

5 Gramm.  
**Este es el zapato con que Pedro aplastó la hormiga cuando estaba aburrido.**  
“This is the shoe with which Pedro crushed the ant when we was bored.”  
Ungramm.  
**Este es el zapato que Pedro aplastó la hormiga con cuando estaba aburrido.**  
“This is the shoe that Pedro crushed the ant with when we was bored.”

6 Gramm.  
**Este es el serrucho con que Eduardo cortó la rama para hacer leña.**  
“This is the saw with which Eduardo cut the branch to make firewood.”  
Ungramm.  
**Este es el serrucho que Eduardo cortó la rama con para hacer leña.**  
“This is the saw that Eduardo cut the branch with to make firewood.”

7 Gramm.  
**Estas son las fotos con que Ana decoró la pared antes de la fiesta.**  
“These are the photos with which Ana decorated the wall before the party.”  
Ungramm.  
**Estas son las fotos que Ana decoró la pared con antes de la fiesta.**  
“These are the photos that Ana decorated the wall with before the party.”

8 Gramm.  
**Este es el lápiz con que Sara dibujó la imagen para su clase de arte.**  
“This is the pencil with which Sarah drew the image for her art class.”  
Ungramm.  
**Éste es el lápiz que Sara dibujó la imagen con para su clase de arte.**  
“This is the pencil that Sarah drew the image with for her art class.”

9 Gramm.  
**Esta es la cinta con que Carlos arregló el cartel cuando se rompió.**  
“This is the tape with which Carlos fixed the poster when it ripped.”  
Ungramm.  
**Esta es la cinta que Carlos arregló el cartel con cuando se rompió.**  
“This is the tape that Carlos fixed the poster with when it ripped.”

10 Gramm.  
**Este es el microondas con que Carlos calentó la sopa antes de cenar.**  
“This is the microwave with which Carlos heated the soup before dinner.”  
Ungramm.  
**Este es el microondas que Carlos calentó la sopa con antes de cenar.**
“This is the microwave that Carlos heated the soup with before dinner.”

11 Gramm. Este es el hacha con que Daniel golpeó el árbol para cortarlo.
“This is the axe with which Daniel hit the tree to cut it.”

Ungramm. Este es el hacha que Daniel golpeó el árbol con para cortarlo.
“This is the axe that Daniel hit the tree with to cut it.”

12 Gramm. Esta es la trampa con que Santiago mató la rata cuando estaba en su casa.
“This is the trap with which Santiago killed the rat when it was in his house.”

Ungramm. Esta es la trampa que Santiago mató la rata con cuando estaba en su casa.
“This is the trap that Santiago killed the rat with when it was in his house.”

13 Gramm. Esta es la lechuga con que Luis hizo la ensalada para la cena.
“This is the lettuce with which Luiz made the salad for dinner.”

Ungramm. Esta es la lechuga que Luis hizo la ensalada con para la cena.
“This is the lettuce that Luiz made the salad with for dinner.”

14 Gramm. Esta es la taza con que Enrique midió la harina cuando horneó el pan.
“This is the cup with which Enrique measured the flour when he baked bread.”

Ungramm. Esta es la taza que Enrique midió la harina con cuando horneó el pan.
“This is the cup that Enrique measured the flour with when he baked bread.”

15 Gramm. Esta es la sal con que Carlos derritió el hielo después de quitar la nieve.
“This is the salt with whichCarlos melted the ice after removing the snow.”

Ungramm. Esta es la sal que Carlos derritió el hielo con después de quitar la nieve.
“This is the salt that Carlos melted the ice with after removing the snow.”

16 Gramm. Este es el palo con que Marta mezcló la pintura antes de pintar la pared.
“This is the stick with which Marta mixed the paint before painting the wall.”

Ungramm. Este es el palo que Marta mezcló la pintura con antes de pintar la pared.
“This is the stick that Marta mixed the paint with before painting the wall.”

17 Gramm. Esta es la clave con que Ana abrió la puerta cuando perdió su llave.
“This is code with which Ana opened the door when she lost her key.”

Ungramm. Esta es la clave que Ana abrió la puerta con cuando perdió su llave.
“This is code that Ana opened the door with when she lost her key.”

18 Gramm. Este es el jabón con que Luis removió la mancha antes de lavar la prenda.
“This is the soap with which Luis removed the stain before washing the garment.”

Ungramm. Este es el jabón que Luis removió la mancha con antes de lavar la prenda.
“This is the soap that Luis removed the stain with before washing the garment.”

19 Gramm. Este es el telescopio con que Carmen vio el planeta cuando miraba las estrellas.
“This is the telescope with which Carmen saw the planet when she was looking at the stars.”

Ungramm. Este es el telescopio que Carmen vio el planeta con cuando miraba las estrellas.
“This is the telescope that Carmen saw the planet with when she was looking at the stars.”

20 Gramm. Esta es la llave con que Pedro rayó el carro cuando estaba enojado.
“This is the key with which Pedro scratched the car when he was mad.”

Ungramm.  *Esta es la llave que Pedro rayó el carro con cuando estaba enojado.*
“This is the key that Pedro scratched the car with when he was mad.”

21  Gramm.  *Este es el cuchillo con que Luis amenazó el vecino después de la pelea.*
“This is the knife with which Luis threatened the neighbor after the fight.”

Ungramm.  *Este es el cuchillo que Luis amenazó el vecino con después de la pelea.*
“This is the knife that Luis threatened the neighbor with after the fight.”

22  Gramm.  *Esta es la cuerda con que Carlos amarró el paquete antes de enviarlo.*
“This is the cord with which Carlos tied up the package before sending it.”

Ungramm.  *Esta es la cuerda que Carlos amarró el paquete con antes de enviarlo.*
“This is the cord that Carlos tied up the package with before sending it.”

23  Gramm.  *Este es el detergente con que Miguel lavó la ropa para quitar las manchas.*
“This is the detergent with which Miguel washed the clothing to remove the stains.”

Ungramm.  *Este es el detergente que Miguel lavó la ropa con para quitar las manchas.*
“This is the detergent that Miguel washed the clothing with to remove the stains.”

24  Gramm.  *Esta es la pluma con que Isabel escribió la carta antes de irse.*
“This is the pen with which Isabel wrote the letter before leaving.”

Ungramm.  *Esta es la pluma que Isabel escribió la carta con antes de irse.*
“This is the pen that Isabel wrote the letter with before leaving.”
APPENDIX F: ACCEPTABILITY JUDGMENT EXPERIMENT EN “IN” SENTENCES

1  Gramm.  Esta es la tienda en que Gonzalo compró el pollo para cocinar la cena.
            “This is the store in which Gonzalo bought the chicken to cook dinner.”
      Ungramm. Esta es la tienda que Gonzalo compró el pollo en para cocinar la cena.
               “This is the store that Gonzalo bought the chicken in to cook dinner.”

2  Gramm.  Esta es la maleta en que Pedro trajo la ropa cuando se fue de vacaciones.
            “This is the suitcase in which Pedro brought the clothing when he went on vacation.”
      Ungramm. Esta es la maleta que Pedro trajo la ropa en cuando se fue de vacaciones.
               “This is the suitcase that Pedro brought the clothing in when he went on vacation.”

3  Gramm.  Esta es la playa en que Andrés enterró el tesoro cuando escapó de la isla.
            “This is the beach in which Andrés buried the treasure when he escaped from the island.”
      Ungramm. Esta es la playa que Andrés enterró el tesoro en cuando escapó de la isla.
               “This is the beach that Andrés buried the treasure in when he escaped from the island.”

4  Gramm.  Este es el pozo en que Ana quemó la basura después de limpiar el jardín.
            “This is the pit in which Ana burned the trash after cleaning the garden.”
      Ungramm. Este es el pozo que Ana quemó la basura en después de limpiar el jardín.
               “This is the pit that Ana burned the trash in after cleaning the garden.”

5  Gramm.  Esta es la trampa en que Carlos atrapó la rata para sacarla de su casa.
            “This is the trap in which Carlos caught the rat to get it out of his house.”
      Ungramm. Esta es la trampa que Carlos atrapó la rata en para sacarla de su casa.
               “This is the trap that Carlos caught the rat in to get it out of his house.”

6  Gramm.  Este es el gimnasio en que Daniel hizo los ejercicios antes del torneo.
            “This is the gym in which Daniel did the exercises before the tournament.”
      Ungramm. Este es el gimnasio que Daniel hizo los ejercicios en antes del torneo.
               “This is the gym that Daniel did the exercises in before the tournament.”

7  Gramm.  Este es el cuarto en que Isabel descubrió la pista después del asesinato.
            “This is the room in which Isabel discovered the clue after the murder.”
      Ungramm. Este es el cuarto que Isabel descubrió la pista en después del asesinato.
               “This is the room that Isabel discovered the clue in after the murder.”

8  Gramm.  Este es el establo en que Enrique examinó el caballo cuando se enfermó.
            “This is the stable in which Enrique examined the horse when it got sick.”
      Ungramm. Este es el establo que Enrique examinó el caballo en cuando se enfermó.
               “This is the stable that Enrique examined the horse in when it got sick.”

9  Gramm.  Este es el cajón en que José encontró la llave cuando la perdió.
            “This is the drawer in which José found the key when he lost it.”
      Ungramm. Este es el cajón que José encontró la llave en cuando la perdió.
               “This is the drawer that José found the key in when he lost it.”

10 Gramm. Esta es la clase en que Luis dio el discurso para su proyecto final.
This is the class in which Luis gave the speech for his final project.

Esta es la clase que Luis dio el discurso en para su proyecto final.

“Esto es el jardín en que Martín cultivó la calabaza antes de la sequía.”

“This is the garden in which Martín grew the squash before the drought.”

“Este es el pasillo en que Gonzalo escuchó el ratón cuando llegó a casa.”

“This is the hallway in which Gonzalo heard the mouse when he got home.”

“This es la carpeta en que María escondió la carta para mantenerla segura.”

“This is the folder in which María hid the letter to keep it safe.”

“This es el bosque en que Isabel vio el oso después de su caminata.”

“This is the forest in which Isabel saw the bear after her hike.”

“This es el banco en que Pedro firmó el documento antes de sacar el dinero.”

“This is the bank in which Pedro signed the document before withdrawing the money.”

“This es el aula en que Miguel derramó el jugo cuando se deslizó.”

“This is the classroom in which Miguel spilled the juice when he slipped.”
20  Gramm.  *Este es el gimnasio en que Julieta entrenó el equipo antes del campeonato.*
    “This is the gym in which Julieta trained the team before the championship.”

     Ungramm.  *Este es el gimnasio que Julieta entrenó el equipo en antes del campeonato.*
    “This is the gym that Julieta trained the team in before the championship.”

21  Gramm.  *Este es el estadio en que Martín ganó el campeonato cuando jugaba fútbol.*
    “This is the stadium in which Martín won the championship when he played soccer.”

     Ungramm.  *Este es el estadio que Martín ganó el campeonato en cuando jugaba fútbol.*
    “This is the stadium that Martín won the championship in when he played soccer.”

22  Gramm.  *Este es el estudio en que Luis escribió la canción antes de ser famoso.*
    “This is the studio in which Luis wrote the song before he was famous.”

     Ungramm.  *Este es el estudio que Luis escribió la canción en antes de ser famoso.*
    “This is the studio that Luis wrote the song in before he was famous.”
APPENDIX G: ACCEPTABILITY JUDGMENT EXPERIMENT COMPLEX NP SENTENCES

1. Gramm. Este es el examen que el padre reconoció que su hija copió.  
   “This is the exam that the father recognized that his daughter copied.”  
   Ungramm. Este es el examen que el padre reconoció la posibilidad que su hija copió.  
   “This is the exam that the father recognized the possibility that his daughter copied.”

2. Gramm. Esta es la pistola que el ladrón admitió que su amigo escondió.  
   “This is the gun that the thief admitted that his friend hid.”  
   Ungramm. Esta es la pistola que el ladrón admitió el hecho que su amigo escondió.  
   “This is the gun that the thief admitted the fact that his friend hid.”

3. Gramm. Esta es la ley que el presidente anunció que el gobierno cambió.  
   “This is the law that the president announced that the government changed.”  
   Ungramm.Esta es la ley que el presidente anunció la noticia que el gobierno cambió.  
   “This is the law that the president announced the news that the government changed.”

4. Gramm. Este es el pueblo que la niña creyó que el héroe salvó.  
   “This is the town that the girl believed that the hero saved.”  
   Ungramm. Este es el pueblo que la niña creyó la historia que el héroe salvó.  
   “This is the town that the girl believed the story that the hero saved.”

5. Gramm. Estas son las inversiones que el analista confirmó que el banco aumentó.  
   “These are the investments that the analyst confirmed that the bank increased.”  
   Ungramm. Estas son las inversiones que el analista confirmó el informe que el banco aumentó.  
   “These are the investments that the analyst confirmed the report that the bank increased.”

6. Gramm. Esta es la chica que la abuela negó que su nieto pegó.  
   “This is the girl that the grandmother denied that her grandson hit.”  
   Ungramm. Esta es la chica que la abuela negó la acusación que su nieto pegó.  
   “This is the girl that the grandmother denied the accusation that her grandson hit.”

7. Gramm. Este es el río que la empresa disputó que la contaminación afectó.  
   “This is the river that the business disputed that the pollution affected.”  
   Ungramm. Este es el río que la empresa disputó el argumento que la contaminación afectó.  
   “This is the river that the business disputed the argument that the pollution affected.”

8. Gramm. Estos son los peces que el profesor dudó que los dinosaurios comían.  
   “These are the fish that the professor doubted that the dinosaurs used to eat.”  
   Ungramm. Estos son los peces que el profesor dudó la teoría que los dinosaurios comían.  
   “These are the fish that the professor doubted the theory that the dinosaurs used to eat.”

9. Gramm. Este es el plato que el cocinero explicó que la hierba mejora.  
   “This is the dish that the cook explained that the herb improved.”  
   Ungramm. Este es el plato que el cocinero explicó la idea que la hierba mejora.  
   “This is the dish that the cook explained the idea that the herb improved.”
10 Gramm.  
_Este es el cuento que la maestra adivinó que el estudiante inventó._
   “This is the story that the teacher guessed that the student invented.”

Ungramm.  
_Este es el cuento que la maestra adivinó la razón que el estudiante inventó._
   “This is the story that the teacher guessed the reason that the student invented.”

11 Gramm.  
_Este es el restaurante que el crítico escuchó que el chef cerró._
   “This is the restaurant that the critic heard that the chef closed.”

Ungramm.  
_Este es el restaurante que el crítico escuchó el anuncio que el chef cerró._
   “This is the restaurant that the critic heard the announcement that the chef closed.”

12 Gramm.  
_Este es el hijo que la chica conocía que el rey ahogó._
   “This is the son that the girl knew that the king drowned.”

Ungramm.  
_Este es el hijo que la chica conocía el mito que el rey ahogó._
   “This is the son that the girl knew the myth that the king drowned.”

13 Gramm.  
_Esta es la oveja que el granjero mencionó que un lobo comió._
   “This is the sheep that the farmer mentioned that a wolf ate.”

Ungramm.  
_Esta es la oveja que el granjero mencionó el descubrimiento que un lobo comió._
   “This is the sheep that the farmer mentioned the discovery that a wolf ate.”

14 Gramm.  
_Este es el edificio que el reportero publicó que la empresa vendió._
   “This is the building that the reporter published that the business sold.”

Ungramm.  
_Este es el edificio que el reportero publicó el rumor que la empresa vendió._
   “This is the building that the reporter published the rumor that the business sold.”

15 Gramm.  
_Este es el bebé que el juez cuestionó que la mujer abandonó._
   “This is the baby that the judge doubted that the woman abandoned.”

Ungramm.  
_Este es el bebé que el juez cuestionó la suposición que la mujer abandonó._
   “This is the baby that the judge doubted the assumption that the woman abandoned.”

16 Gramm.  
_Estas son las pirámides que el estudiante leyó que la civilización construyó._
   “These are they pyramids that the student read that the civilization built.”

Ungramm.  
_Estas son las pirámides que el estudiante leyó la hipótesis que la civilización construyó._
   “These are they pyramids that the student read the hypothesis that the civilization built.”

17 Gramm.  
_Este es el telescopio que el científico rechazó que los italianos inventaron._
   “This is the telescope that the scientist rejected that the Italians invented.”

Ungramm.  
_Este es el telescopio que el científico rechazó la creencia que los italianos inventaron._
   “This is the telescope that the scientist rejected the belief that the Italians invented.”

18 Gramm.  
_Esta es la evidencia que el prisionero repitió que el policía escondió._
   “This is the evidence that the prisoner repeated that the police hid.”

Ungramm.  
_Esta es la evidencia que el prisionero repitió la afirmación que el policía escondió._
   “This is the evidence that the prisoner repeated the statement that the police hid.”
19 Gramm.  *Estas son las drogas que la investigadora reportó que el atleta tomó.*
“These are the drugs that the investigator reported that the athlete took.”

Ungramm.  *Estas son las drogas que la investigadora reportó la conclusión que el atleta tomó.*
“These are the drugs that the investigator reported the conclusion that the athlete took.”

20 Gramm.  *Estas son las caries que el dentista reveló que la bacteria causó.*
“These are the cavities that the dentist revealed that the bacteria caused.”

Ungramm.  *Estas son las caries que el dentista reveló la explicación que la bacteria causó.*
“These are the cavities that the dentist revealed the explanation that the bacteria caused.”

21 Gramm.  *Este es el pueblo que el bombero grito que el incendio destruyó.*
“This is the town that the firefighter yelled that the fire destroyed.”

Ungramm.  *Este es el pueblo que el bombero grito el mensaje que el incendio destruyó.*
“This is the town that the firefighter yelled message that the fire destroyed.”

22 Gramm.  *Este es el puente que el ingeniero mostró que el terremoto dañó.*
“This is the bridge that the engineer showed that the earthquake damaged.”

Ungramm.  *Este es el puente que el ingeniero mostró la evidencia que el terremoto dañó.*
“This is the bridge that the engineer showed the evidence that the earthquake damaged.”

23 Gramm.  *Estas son las monjas que el cura entendió que la película ofendió.*
“These are the nuns that the priest understood that the movie offended.”

Ungramm.  *Estas son las monjas que el cura entendió el tema que la película ofendió.*
“These are the nuns that the priest understood the issue that the movie offended.”

24 Gramm.  *Este es el concierto que el autor escribió que el cantante arruinó.*
“This is the concert that the author wrote that the singer ruined.”

Ungramm.  *Este es el concierto que el autor escribió la opinión que el cantante arruinó.*
“This is the concert that the author wrote the opinion that the singer ruined.”
REFERENCES


