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The Influence of Language Experience on Emotional Processing and Language Regulation in Bilingual Speakers

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Education

by

Nicole Annette Vargas Fuentes

Dissertation Committee:
Distinguished Professor Judith F. Kroll, Chair
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2026

DEDICATION

To my parents; ustedes me lo han dado todo y por eso yo lo puedo dar todo en lo que hago. To my family in Puerto Rico, thank you for always being the home I can go back to. To my friends that I have made throughout my graduate program; you were the family I made here.

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ABSTRACT OF THE DISSERTATION

The Influence of Language Experience on Emotional Processing and Language Regulation in Bilingual Speakers

by

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Doctor of Philosophy in Education

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Distinguished Professor Judith F. Kroll, Chair

Bilingual speakers constantly regulate the activation of their two languages, even when only one language is being used. Research on bilingual language regulation suggests that the characteristics of bilinguals' interactional contexts shape how they engage domain-general cognitive mechanisms that support language regulation. Language, however, does not operate in an emotional void. Emotions can influence cognitive processes implicated in language regulation, while emotional processing itself may vary across a bilingual's two languages and as a function of their language experiences. In this dissertation, we examine how emotional processing influences bilingual language regulation, as well as how bilingual language experiences may, in turn, shape emotional processing.

The first study compared three groups of bilingual speakers with distinct language experiences and interactional contexts: Spanish-English late bilinguals in Mexico and two groups of heritage speakers (Spanish and Mandarin) in Southern California. Participants completed a series of language tasks and a language history questionnaire to measure their sensitivity to different behavioral indices of language regulation, including reversed dominance, block-order effects, and mixing costs. They also completed a cued language-switching task interleaved with emotion words to examine the effects of positive and negative words on subsequent language switching. Results revealed variation in these indices of language regulation across the three groups, supporting frameworks in which interactional context is proposed to shape bilingual

language regulation. Although our results did not replicate prior findings of reduced switch costs following negative words, emotional information nevertheless influenced language production, suggesting that its effects on bilingual language regulation may extend beyond traditional measures of behavioral switch costs.

The second study examined the relationship between emotion and language regulation in Spanish-English heritage bilinguals using behavioral and electrophysiological measures. Participants completed an extended version of the emotion language switching task from the first study while EEG data was recorded. Event-related potentials were stimulus-locked to both the presentation of the emotion words and the picture naming trials in order to examine the temporal dynamics involved in both emotional processing and language regulation. Emotional word processing revealed that cross-linguistic differences in sensitivity to emotional valence appeared later in processing but only when considering language dominance. During language switching, effects of negative words on switch trials emerged across different stages of language switching including early engagement of cognitive control (N2), lexico-semantic processing (N400) and re-evaluation preceding production (LPC). Cross-linguistic differences in these emotion-related effects became particularly evident during later stages of the switching process.

Taken together, these two studies highlight the role of language experience both on emotional processing, language regulation, and their intersection. Bilingual speakers in different interactional contexts showed different sensitivity to demands on language regulation as seen in study 1. While we failed to replicate prior findings on the effect of emotion on language switching using behavioral measures, ERP data from the second study revealed an effect of negative words on switch trials. The influence of emotions on language switching seems to unfold across multiple processes with cross-linguistic differences emerging in later stages of

processing. Finally, our findings suggest that emotional processing is modulated by language experience which goes against traditional claims of emotional processing being constrained and unchanged in the native language.

CHAPTER 1: Introduction

A foundational discovery about bilingualism is the parallel activation of a bilingual's two languages. Whenever bilinguals read, write or speak in one language, both languages are active (Kroll & Ma, 2017). The implications of this parallel activation are two-fold. First, parallel activation creates competition between both sets of linguistic information that must be managed for bilinguals to use the target language. Cognitive control is speculated to be an underlying mechanism that supports this language regulation (Abutalebi & Green, 2008). Second, parallel activation suggests a dynamic cross-linguistic system with more openness and plasticity than previously presumed. In this open system, both the first (L1) and second (L2) language influence each other at all levels of language processing.

Although there is substantial evidence of the openness and plasticity of cross-language interactions in bilinguals, a striking exception has been reported in research on emotion. Many studies have reported attenuated emotional processing and reactivity in the non-native language of bilinguals. Evidence demonstrating reduced emotionality in the L2 has been found for self-reported narratives (e.g., Dewaele, 2006), physiological measures (e.g., skin responses; Harris, 2004), and brain activity (e.g., Fan et al., 2016). Based on these findings, emotions would seem to not be shared in the open system across the bilingual's two languages. However, it is important to note that the claims about enhanced emotion for L1 and reduced emotion for L2 emerge from observations of late bilinguals—those who acquired an L2 later in life, typically in a formal schooling context, and are immersed in the L1. Research examining bilinguals who deviate from that language pattern (e.g., Harris et al., 2006; Vargas Fuentes et al., 2022; Thoma, 2024) suggests a greater openness in the language-emotion dynamic.

Emotions can alter cognitive processes such as attention, inhibitory control, and working memory (see Pessoa, 2008, for a review), making differences in how bilingual speakers process emotional information across their two languages particularly important. For example, studies have reported that processing information in a nonnative language can affect decision-making by reducing susceptibility to loss aversion and framing effects (Keysar et al., 2012; Xing, 2021), as well as shifting responses to moral dilemmas (Geipel et al., 2015; Hayakawa et al., 2017). One proposed explanation for this foreign language effect is attenuated emotional reactivity in the L2, which may reduce the influence of affective heuristics on decision-making.

More recently, studies have examined another potential influence of emotion on bilingual language processing, specifically on language regulation. Emerging evidence (e.g., Liu et al., 2023; Wang et al., 2024) suggests that emotion may influence language switching through its effects on cognitive and inhibitory control. In particular, studies have reported reduced switch costs after processing negative content, such as words (Liu et al., 2024; Liu et al., 2026a), or following the induction of negative emotional states (Wang et al., 2024). Negative information may engage inhibitory processes (Zinchenko et al., 2015), which could facilitate subsequent language switching. Yet relatively little is known about the temporal dynamics of emotional influences on language regulation and how bilingual language experience, which has been shown to shape emotional processing, may modulate these effects.

This dissertation addresses these questions by discussing findings from two main studies. **Study 1** takes a cross-cultural approach to investigating the role of interactional contexts in the effect of emotions on bilingual language regulation. We compared three groups of bilingual speakers with distinct language experiences and interactional contexts: Spanish-English late bilinguals in Mexico, and to groups of heritage speakers in Southern California (Spanish and

Mandarin). Participants completed a series of language production tasks and a language history questionnaire which provided behavioral measures to observed each group's sensitivity to language regulation demands. To examine the effect of emotion on language regulation, we adopted the paradigm used in Liu et al. (2023) which includes a language switching picture naming task interleaved with an emotion word classification task.

Study 2 extends the paradigm from the first study by collecting both behavioral and electrophysiological data from a new group of Spanish-English heritage bilinguals. Event-related potentials (ERPs) were extracted to analyze both emotional word processing and language switching across different stages of processing. This design allowed for a temporal view into the effect of emotions on language switching as well as into emotional processing itself.

In the following chapter, we provide an overview of the relevant literature and theoretical background for both studies (Chapter 2). Chapters 3 and 4 then present the findings from Study 1 and Study 2, respectively. These chapters were written as potentially publishable manuscripts for each study. Therefore, some redundancy exists across the chapter introductions, as each was written to function both as an independent manuscript and as part of the broader dissertation. Finally, Chapter 5 concludes with a general discussion of the findings across both studies and their broader theoretical implications.

CHAPTER 2: Theoretical Background

Bilingual Language Regulation

When bilinguals produce or process speech, linguistic information at all levels (e.g., words, structures) from both languages are activated (Kroll & Ma, 2017). Bilinguals must deal with the competition arising from this parallel activation in order to functionally communicate in one language. To do so, the working hypothesis is that they regulate the activation of the non-target language (Abutalebi & Green, 2008). Evidence for this co-activation and language regulation comes from studies on language switching in spoken production. In language switching tasks, the need to regulate each language is manipulated by randomly cueing one language or the other and forcing bilinguals to switch languages.

Meuter and Allport (1999) had L2 learners complete a cued lexical production switching task where numbers were presented inside colored frames which indicated the target language (English or L2). Half of the trials consisted of stay/non-switch conditions where the target language preceding the trial was the same (i.e., English-English or L2-L2 consecutive trials). The other half were switch trials (i.e., English-L2, L2-English). Overall, they found that not only does switching languages produce a cost in speaking, but the cost is greater when switching back to the dominant L1 English. This language dominance reversal (e.g., Declerk et al., 2020) suggests that the allocation of cognitive resources is not uniform across languages—inhibiting the response of a dominant language requires more cognitive effort.

The Inhibitory Control (IC; Green, 1998) model provides an explanation for switch costs and language reversals. Language is a communicative action that operates on specific goals (e.g., naming a number in a specific language). As any action, it relies on the activation of relevant mental networks and must be monitored in order to ensure goal compliance. Whenever bilinguals plan speech (goal), the target conceptual representation will activate both L1 and L2 lemmas (relevant information). Lemmas, in turn, have features that not only relate to the conceptual representation but also to each language through what Green (1998) refers to as language tags. At some point during the stage of selection for output, incorrect language tags must be suppressed. Given the difference in lemma-conceptual links between the L1 and L2 (see Revised Hierarchical Model for an account on bilingual lexicons; Kroll & Stewart, 1994), the activation across the two languages is not equal. The stronger lemma-conceptual link of the L1 results in stronger activation. Inhibiting incorrect language tags with strong activations requires more inhibitory engagement. The IC model predicts switch costs in bilingual speech production either caused by the change of language schema during the task or the need to overcome prior inhibition of the target language.

Since inhibitory control is differentially exerted in each language given the strength of activation, changes to the lemma-conceptual link, and therefore activation, should affect switch costs. In particular, the IC model would predict that an equal strength of activation in the L1 and L2 should result in symmetrical results. Evidence for this claim comes from language switching studies with balanced or highly proficient bilinguals. Costa and Santesteban (2004) compared the performance of L2 learners and highly proficient bilinguals in a language switching design using pictures. They replicated the asymmetrical switch costs for L2 learners; switching back to the dominant L1 after naming in the weaker L2 produces longer naming latencies than vice versa. However, the highly proficient Spanish-Catalan bilinguals showed no asymmetrical costs. Switch costs were present for both languages but in an equal effect. Symmetrical switch costs have been found consistently (e.g., Timofeeva et al., 2023) when looking at highly proficient and balanced bilinguals. Both asymmetrical and symmetrical switch costs suggest a language regulation mechanism that occurs across different levels of bilingual proficiency and that is sensitive to relative activation of each language.

The Adaptive Control hypothesis proposed by Green and Abutalebi (2013) argues that the interactional context—that is, the context in which bilinguals use their languages—incurs certain demands that shape the engagement of goal-oriented cognitive processes and, by consequence, language regulation. Green and Abutalebi describe three different language contexts (single language, dual language and dense codeswitching) to provide a framework for how interactional context places different demands on cognition. For example, in a context where either language could be used (dual language), bilinguals must constantly keep in mind the target language (goal maintenance), inhibit the non-target language (interference suppression) while still be on the lookout for speakers of either language (salient cue detection). In a single language context, there might be less need for salient cue detection, and the non-target language can be proactively suppressed (conflict monitoring) in preparation. It is important to note that interactional contexts are ever changing and, even within the same context, bilingual speakers may differ in their interactions. The Adaptive Control hypothesis accounts for such variation by situating adaptation to contextual demands as a key feature of language regulation. Evidence for such adaptation can be seen when we examine manipulations to immediate contexts in the laboratory, cross-cultural comparisons, and individual differences.

In the laboratory, we can manipulate the immediate language context by providing certain constraints in bilinguals' language production. Most of the research on language switching is designed with an equal switch-to-nonswitch ratio. That is, the number of switches to each language is controlled for and comparable to nonswitch trials. This equal ratio is not necessarily representative of the context bilinguals face in their lives. Languages can be somewhat predictable given that a language typically dominates in a specific context. Olson (2016) and Timmer et al. (2019) examined how language context affects switch costs.

Olson (2016) had highly proficient Spanish-English bilinguals, some L1 Spanish dominant and others L1 English dominant, complete a cued picture naming switching task in three distinct contexts. Two contexts were deemed *monolingual contexts* in either Spanish or English where 95% of the pictures were named in one language. The third context was the *bilingual context* which had a 50/50 equal ratio for Spanish and English. After collapsing by L1 dominance, asymmetrical switch costs were more pronounced in the L1 monolingual context than in bilingual context. That is, L1 Spanish dominant bilinguals showed a larger switch cost in the Spanish monolingual context in comparison to the 50/50 bilingual context; the same was found for L1 English dominant bilinguals in the English monolingual context. Dominant languages imply stronger activation of lexical items which means managing stronger interference when engaging in the weaker language. Olson argues that making the dominant L1 more salient in the monolingual context demands an unequal distribution of inhibition on the two languages. Such unequal distribution results in asymmetrical switch costs while, in the bilingual context, switch costs are symmetrical across the two languages given the equal exertion of inhibition.

In Olson (2016), a discussion of what happens to L1 dominant speakers in the L2 monolingual context was not included. However, Timmer et al. (2019) sought to address whether the asymmetrical switch costs can occur for the weaker L2 in L2 dominant contexts. Using a similar design, Timmer et al. manipulated the ratio of L1/L2 pictures, creating either L1 Dutch dominant contexts or L2 English dominant contexts. They replicated the typical L1 asymmetrical switch costs in the L1 dominant context and, most interesting, found L2 asymmetrical switch costs in the L2 dominant context.

Convergently, these two studies using cued picture naming in either L1/L2 dominant contexts (e.g., 90% of the trials were in one language) or in mixed bilingual contexts (i.e., 50/50) showed different switch costs depending on context. These results align with the IC framework where lexical activation across the two languages is influenced by the language's salience in its environment: resulting in inhibitory control to be differentially enforced for each language. From a broader perspective, these laboratory results suggest that bilinguals are able to exploit the context in order to fine tune their regulatory demands. This ability to exploit contextual cues is remarkable and appears to depend on prior language experience and also the engagement of cognitive resources.

Another approach to test the predictions of the Adaptive Control hypothesis has been done by comparing bilingual populations in different locations. Beatty-Martínez et al. (2020) tested three Spanish-English bilingual groups in Spain, Puerto Rico and the U.S. In particular, they questioned whether interactional contexts could predict different reliance on cognitive control for speech production. Cognitive control includes general cognitive skills that are used for task completion which include attention, inhibition, updating and shifting. Many past studies have used the AX Continuous Performance Task (AX-CPT; Braver, 2012), a nonlinguistic measure of cognitive control, to predict performance in speaking each language. The AX-CPT provides an index of two approaches: proactive and reactive control. When speakers are proactive, they are sensitive to goal-relevant information and prioritized cues in the environment that may be relevant to predictive processing. Bilinguals may engage in a proactive control strategy when the environment requires that they monitor for the presence of speakers with whom they can use each of their languages. In contrast, contexts in which there is greater certainty about the circumstances under which each language is used, may favor reactive control strategies.

Bilinguals may find themselves navigating these two types of immersive contexts which alters their engagement with proactive and reactive control strategies.

Beatty-Martinez et al. (2020) found that Spanish-English bilinguals living in an L1-dominant environment where the two languages were used separately (i.e., Spain) relied on more reactive strategies while those immersed in an L2-dominant environment where there was uncertainty about who spoke their L1 (i.e., Pennsylvania) relied on more proactive strategies. Both groups were comparable in terms of proficiency in the two languages, which suggests that the difference stems from their language immersive context.

Bilingualism and Emotions

The prominent claim that kickstarted the work on emotion and bilingualism research is that the native language (L1) is the hub for emotional processing. Emotions in another language feel less intense, less arousing and their processing is less automatically. While there is not one single hypothesis or account to explain the emotional language discrepancy, there is a consensus as to the privilege of early age of acquisition and sustained language dominance. In general, accounts explaining L2 reduced emotionality can be categorized as either age of acquisition, context or processing-based accounts (Thoma, 2021).

Age of acquisition accounts

Early life is a crucial period for all sorts of developmental trajectories including linguistic, cognitive, and emotional processes. In the typical case of late bilinguals, the L1 is acquired during childhood with high levels of exposure and input in a naturalistic context. This early and highly interactive learning environment represents a period marked by an 'openness' to create meaningful links between language and emotions. During childhood, there is a parallel development of the native linguistic system and the emotional system (Eisenberg et al., 2005).

Some argue that this parallel development results in a highly intertwined L1-emotion link (Pavlenko, 2012). Meanwhile, the second language, in the case of late bilinguals, is typically acquired in an instructed context with less exposure and input outside the classroom. Critically, the L2 is learned while still immersed in an L1-dominant environment which has direct consequences for the cultural and personal connection that can be established with the L2.

The privilege of early life experiences in emotion and language can be examined by the growth of emotion vocabulary. Baron-Cohen et al. (2010) surveyed the parents of children and actual adolescents in the UK from ages 4 to 16 and found that emotion vocabulary doubles every two years in early childhood (4-11 years) but decreases its grow rate after age 12. In particular, children typically learn the basic emotions (e.g., anger, sadness, joy) and then developed vocabulary for what are commonly referred to as complex emotions (e.g., jealousy, shame) that stem from the basic ones (Streubel et al., 2020; Baron-Cohen et al., 2010). Such pattern of acquisition suggests the existence of a hierarchical order of emotions that holds to be true cross-linguistically and culturally (Jackson et al., 2019).

The importance of successfully acquiring emotion vocabulary is evident when we look at children's emotion regulation behavior. Knowing that the word '*sad*' refers to the emotional and physiological state of sadness helps a child express their emotional state without necessarily having to externalize it (i.e., crying, tantrum). Streubel et al. (2020) studied the role of emotion-specific vocabulary in emotion understanding in 4- to 9-year-old German monolingual children. They sought to examine how emotion-specific vocabulary size (i.e., the number of emotion words a child knows) and depth (i.e., the similarity of children's use of emotion words to adult's use) played a role explaining individual differences in children's emotional understanding (e.g., facial emotion recognition). They replicated the usual positive relationship between vocabulary size and children's emotion recognition ability and emotional regulation strategies. However, in the case of 8- to 9-year-old children, emotion-specific vocabulary size ceased to be a good predictor of emotion understanding behavior. Streubel et al. argued that a boost of vocabulary size that is not accompanied by depth might be detrimental to children's emotion understanding since they might tentatively or even inaccurately use new emotion words.

In general, early childhood is a crucial period for emotion vocabulary and seemingly emotion regulation. What happens with bilingual children? Ahn and Chang (2022) examined the emotion word development trajectory of three type of Korean child users: children that used Korean as a majority language but not inside the home (e.g., English speakers living in Korea), children that used Korean in the home but not outside (i.e., Korean heritage speakers living in the U.S.) and children that used Korean both at home and outside (i.e., Korean speakers living in Korea). The children's age ranged from 4-13 years old and their emotional rating of Korean emotion words was compared to Korean adults' rating to see how much they deviate or approximate adult knowledge. While all age groups showed adult-like emotional rating by the ages of 11 to 13 years old, children that spoke Korean only at home did not continue the pattern of vocabulary growth in the later ages. That is, in the ages of 11-13 years, Korean heritage speakers living in the U.S. reported knowing less words than their counterparts and deviated from the path of obtaining adult-like emotion vocabulary knowledge. Such evidence illustrates the impact of language environment on emotion vocabulary. Even though children might receive the necessary input to develop emotion vocabulary, the lack of opportunities to use it and the dominance shift to the other language prompted by their language environment can potentially attrite their emotion vocabulary.

Looking at older bilinguals, we can examine the consequences of early life experiences in L1 and L2 emotional processing. Weimer and Koniakowsky (2022) tested Russian immigrants in Germany with different ages of arrivals which is a proxy for L2 age of acquisition. They completed a word detection task in both L1 Russian and L2 German where some of the words where either neutral or taboo. An emotion effect was found for the L1 where taboo Russian words were recognized better than neutral words. However, when looking at individual level performance, Weimer and Koniakowsky found an age of arrival effect: those arriving after mid-adolescence showed language effects (L1 > L2) but those who arrived earlier did not (L1 ~ L2).

Harris (2004) found that, in comparison to late language learners, early learners of English showed comparable emotional reactivity across their two languages as evidenced by skin conductance responses. This finding is in line with accounts of age of acquisition in which a critical period for emotional resonance in the L2 can be assumed. However, Harris et al. (2006) compared two groups of late language learners (Harris, 2004 and Harris et al., 2003) and concluded that the group which reported higher proficiency in the L2 showcased less difference in their emotional reactivity. This effect of proficiency suggests that emotion is not only driven by age of acquisition and that there is greater openness to the emotion-language dynamic than previously thought.

In general, it is hard to encapsulate in definite age brackets the special period of early life that results in reduced emotionality in the L2. Caldwell-Harris and MacWhinney (2023) argue that instead of considering age of acquisition effects as results of the closing of critical or sensitive periods, they should be considered to reflect cognitive, biological and social constraints that change across the lifespan. Following a similar logic, context-based accounts emphasize those constraints that may be at play when bilinguals not only acquire but actively use their languages.

Context-based accounts

Context-based explanations also emphasize the unique and privileged experience of L1 acquisition. During early childhood, the L1 is acquired in a naturalistic environment with children being exposed to their native language and acquiring it without formal instruction. Meanwhile, L2 acquisition is distinctly marked by circumstances different from those in early life. In the case of late bilinguals, those who learn a second language later in life, the L2 is acquired in formal settings (e.g., school). They may have less opportunities to utilize and be exposed to the language, resulting in less meaningful links between the language and emotions.

Language is used in context and context provides rich sensorial input that enriches our encoding and understanding of language. Pavlenko (2005, 2012) put forth the theory of language embodiment which details “affective socialization in early childhood as the process of integration of phonological forms of words and phrases with information from visual, auditory, olfactory, tactile, kinesthetic, and visceral modalities, autobiographical memories, and affect” (Pavlenko, 2012). While the context of early childhood is ideal for the development of an embodied L1 system, affective socialization is not exclusive to early life experiences. That is, if the bilingual uses and is exposed to the L2 in context that may foster such connections, then it is expected to see higher degrees of L2 emotionality. There is evidence (Vargas Fuentes et al., 2022; Herbert, 2023), showing that bilinguals who experience higher affective socialization in their second language may be able to strengthen those links.

In Vargas Fuentes et al. (2022), an emotion-memory paradigm was used to test emotional processing in Spanish heritage speakers who have had a lifelong immersion in an English-dominant society. In particular, they investigated whether the degree of their language dominance shift to the societal language predicted more pronounced emotion effects. As predicted, the higher their dominance in English, the more prominent the emotion-memory effect in their performance (i.e., emotion words are recognized to a higher degree). Critically, their higher recognition of emotion words could not be explained when we only looked at age of acquisition or proficiency in English. While there are language aspects that still need to be examined as to how they affect the emotion-language link (e.g., biculturalism), this initial evidence speaks of (1) a more open and dynamic language-emotion interaction than previously thought and (2) the predictive strength of language dominance. That is, emotional processing may track with language dominance and carry over when language dominance shifts—a consequence that is inherently related to the demands of language context.

It is important to note that dominance is not necessarily determined by proficiency or age of acquisition. Birdsong et al. (2012) conceptualizes it as a multidimensional construct that considers the history, the use, the perceived proficiency and the attitudes a bilingual has towards their two languages. Dominance is inherently ever-changing and reflective of the current internal (e.g., motivation, identity) and external (e.g., linguistic community) demands of a bilingual's two languages. Crucially, shifts in language dominance can result from both short term (e.g., laboratory, studying abroad) and lifelong (e.g., immigration) L2 immersive contexts.

Processing-based accounts

While age of acquisition and context-based accounts give more importance to the links that are drawn between L1/L2 lexical items and emotions given certain contexts of learning and use, processing accounts argue that the L1-L2 emotional asymmetry is due to a processing cost. Processing information, selecting lexical items, and planning and producing speech in a less proficient language is cognitively effortful (see Cargnelutti et al. (2019) for evidence with imaging data). When processing emotional stimuli in a less proficient language, bilinguals may struggle to process the words and may take longer to decode its meaning. Attentional and cognitive resources are spent on decoding and/or producing the weaker L2 to the point no resources are left for in depth emotional processing (Kron et al., 2010). This is not the case for the highly proficient L1 in which words are processed with ease and automaticity.

The same way that processing cost may be exacerbated by circumstances, they can also be mitigated. Bilinguals who become more proficient in their L2, given an increase in their language use and exposure, may lessen L2 processing costs. Following this logic, highly proficient bilinguals should not demonstrate a pronounced L1-L2 emotional asymmetry given that they have a relative ease of processing in both languages. Thoma (2021) manipulated the allocation of attentional resources when unbalanced German-English bilinguals read emotional words. Differences in emotional resonance decreased when the automaticity of the L1 was stumped (e.g., adding math distractors in between emotional ratings) and when there was an opportunity to ruminate on emotions in the L2. These findings suggest a more flexible interplay between emotion and language, shaped by both cognitive demands and language experiences. By leveraging the unique experiences of different bilingual populations, it is possible to deepen our understanding of how language exposure and cognitive requirements influence this dynamic.

In summary, when looking at the experience of late bilinguals, there is strong evidence that the claim of L2 reduced emotionality. However, when we look beyond the late bilingual experience, a pattern of greater openness for emotional processing in bilinguals emerges. Studies looking at the experience of early bilinguals (e.g., Harris, 2004) and heritage bilinguals (Vargas Fuentes et al., 2022; Thoma, 2024) show higher than expected levels of emotional resonance in the L2. The remaining question is what makes a language emotional? In order to understand how age of acquisition, exposure, proficiency or dominance contribute to the emotional processing in a language, different bilingual experiences must be considered.

Bilingualism, Cognition and Emotion

The present dissertations seeks to understand bilingual emotional processing in order to address the openness and plasticity of the bilingual language system. However, even outside of bilingualism research, the interactions between emotion and cognition have been of research interest to cognitive, psychological and affective sciences. In the following section, links between emotion and cognition are described to situate the proposed dissertation. The section concludes with initial evidence pertaining to the effect of emotion on language regulation.

Emotion and Cognition

In simplified terms, emotions are the result of subjective experiences that provoke physiological arousal and behavioral expressions (Inzlicht et al., 2015). From an evolutionary perspective, emotions serve as guides to our behavior and ultimate survival. We naturally seek to avoid situations of emotional peril such as fear, hurt and sadness, and increase frequency of emotional highs such as joy, happiness, and pride. Some scholars argue that there is no cognitive process that is void of affect and situate emotional regulation at the center of all cognitive behavior (see Pessoa (2008) for a review on the debate). While the distinction between emotional and domain-general cognitive processes is not the focus of the proposed work, we draw upon the overlaps emotional processing, emotional regulation and cognition to draw connections to language regulation.

Emotions are complex physical and psychosocial phenomena and regulating them requires the involvement of bodily and cognitive systems working in tandem to process input, appraise, and ultimately enact goal-oriented behaviors. While basic emotions may have guided our behavior in the past in order to survive, regulating emotions has become a survival skill on its own. As humans evolved to live in society, emotions that provoke maladaptive behavior (e.g., anger may provoke an outburst) needed to be regulated. To that aim, humans evolved to have a sophisticated emotion regulation system in comparison to other mammals.

Emotion regulation is defined as goal-directed behavior that attempts to influence how we feel, when we feel, and how we react or express those feelings (Gross, 1999). Research examining the mechanisms that enable emotion regulation has pointed to the involvement of domain-general cognitive mechanisms, specifically cognitive control which is commonly referenced in accounts explaining both regulation of emotions (Pruessner et al., 2020; Agudelo-Orjuela et al., 2021; Hendricks & Buchanan, 2016) and language (Abutalebi & Green, 2008). Two different mechanisms have been hypothesized to underlie emotion regulation. One is more deliberate whereby individuals recognize an emerging emotion and consciously decide to regulate it. The other is more automatic and potentially under the awareness of the individual. This automatic activation of emotion regulation is the key basis for research investigating the effects of emotions on cognition. For example, Zinchenko et al. (2015) found that negative stimuli directly influence conflict resolution performance on a Stroop task as evidenced from faster reaction times on incongruent trials. Negative emotions appear to activate the automatic pathway of emotion regulation and engage cognitive control processes such as inhibition. In a more extreme view, Inzlicht et al. (2015) argue that cognitive control depends on emotion since conflict is inherently negative in affect.

Emotion and Language Regulation

To our knowledge, one of the first studies looking at the effect of emotion on language regulation is Liu et al. (2023). They investigated the influence of emotions in a switched picture naming paradigm. Mandarin-English bilinguals living in an L1-dominant environment named pictures in a mixed-language block while also completing an emotion judgment task. Participants were presented with either positive or negative words in L1 (Mandarin) or L2 (English). Then they completed a picture naming trial in either the same language as in the emotion judgment (non-switch) or in a different language (switch). As expected, naming latencies on switch trials were longer but only after participants were presented with a positive word. When presented with a negative word, naming latencies between switch and non-switch trials were equivalent. Liu et al. also reported converging brain imaging data using functional magnetic resonance imaging (fMRI). They found greater activation in brain regions related to cognitive control, language processing, and emotion processing in switch trials after exposure to positive words. The opposite pattern was true for the negative word condition where they found reduced activation in switch trials compared to non-switch.

Liu et al. argued that negative words activated an inhibition process which affected the language of presentation. By itself, emotional processing is a complex multidimensional phenomenon for monolingual and bilingual speakers alike. Emotions, from an evolutionary perspective, serve as guides to our behavior and ultimate survival (Gross, 1999). As humans, we are innately wired to perceive and avoid situations where negative feelings may arise such as danger or potential hurt. Such evolutionary wiring makes negative information, be it words, sounds or images, to be highly salient in our environment and processed automatically. To process and properly react to emotional stimuli, humans have developed a highly sophisticated emotion processing and regulating system which engages domain-general cognitive control

(Pruessner et al., 2020)—mechanisms also believed to underly language regulation. It is this automatic avoidant result from the emotion system that seems to interact with language regulation and effectively reduce switch costs. Thus, switching away from the language in which the negative word was presented was easier since negative words preemptively engaged language regulation. The work from Liu et al. provides preliminary evidence as to the relationship between emotion, language regulation, and inhibition. The alternating design of this paradigm follows the logic of prior work examining language and inhibition (Hsu & Novick, 2016) and emotion and inhibition (Agudelo-Orjuela et al., 2021).

Since the Liu et al. (2023) study, other studies have reported similar patterns. Wang et al. (2024) provide initial evidence that positive and negative emotions may influence different stages and directions of language switching through a mood induction paradigm. Behaviorally, happy mood facilitated switching into L1, improving both accuracy and response speed. Meanwhile, fearful mood facilitated the speed of switching into L2. The electrophysiological revealed that happy mood modulated L1 switch trials across the P1, N2, and N400 components, while fearful mood modulated L2 switching through enhanced N400 and N600 responses. The authors interpreted these effects as evidence that emotion can influence switching from early attentional and control processes through later lexical-semantic processing.

More recently, Liu et al. (2026a) examined whether the influence of emotional states on language switching varies with the frequency of switching (25%, 50%, or 75% switch trials) after being induced into neutral, positive, or negative emotional states. They found that the influence of emotional state differed across switching contexts. In the 50% switching condition, negative states were associated with a reduced N2 for switch trials, an effect that was absent in the 25% and 75% conditions. At the highest switching frequency (75%), emotional states modulated P3 responses during the Flanker trials with positive states producing larger P3 amplitudes for incongruent trials and negative states producing larger P3 amplitudes for congruent trials. Within their proposed Emotion Adaptive Control framework, Liu et al. (2026a) interpret the N2 findings as evidence that negative emotion facilitates the allocation of cognitive resources when switching demands are moderate. At higher switching frequencies, the P3 findings suggest that positive states promote proactive control and negative states promote reactive control.

In summary, emotion, cognition, and language are inherently interconnected processes. Emotional processing is supported by domain general cognitive processes but emotions also influence how those cognitive processes are engaged. Some of these cognitive processes such as inhibition and cognitive control overlap with language regulation. Emerging evidence suggests that emotion, specifically negative words, can affect language regulation by preemptively engaging cognitive control. As consequence, switching languages is facilitated. The present dissertations used an adapted design from Liu et al. (2023) to test this effect across different populations and with electrophysiological data. This approach allows for the opportunity to understand how different language experiences may affect both linguistic, emotional and cognitive processes.

CHAPTER 3: Emotion and Bilingual Language Regulation Across Interactional Contexts

Abstract

Studies have found that bilingual speakers regulate their two languages depending on the contextual demands of the interactional context (e.g., single language or mixed language use). Yet social interactions are rarely emotionally neutral, and few studies have examined how emotion may affect bilingual language regulation and how such effects may differ across interactional contexts. In this study, three groups of bilingual speakers (Spanish-English bilinguals in Mexico, US Spanish heritage speakers and US Mandarin heritage speakers) completed a cued-language picture naming task while simultaneously classifying emotional words as either positive or negative. They also completed a language history questionnaire, a semantic verbal fluency task, and pure language picture naming blocks. Triangulating these data, we examined three distinct indexes of language regulation (i.e., reversed dominance, order effects, and mixing costs). We found an effect of negative words in overall naming speed but no interaction with switching. This effect was not dependent on language or bilingual group although each group showed different sensitivity to indexes of language regulation.

1. Introduction

Bilingual speakers are constantly managing the dual activation of their languages. Many researchers have focused on examining the cognitive mechanisms that make this language regulation possible, pointing to the involvement of domain-general cognition. Yet language rarely happens in an emotionally neutral environment. Conversations can be positive, like the news of a promotion, or negative, like the passing of a loved one. Emotional information can capture attention and alter ongoing cognitive processing, like suddenly hearing an alarm and switching to surveillance mode. This raises an important question: how does emotion interact with the mechanisms that allow bilinguals to manage their languages?

Although there is substantial research on bilingual language regulation and an expanding body of research on bilingualism and emotional processing, relatively little is known about how emotion affects language regulation (Liu et al., 2023; Wan et al., 2024; Liu et al., 2026a). Even more so, in the limited literature, no attention has been paid to the interactional contexts that may affect both emotional and language processing. In the present study, we compared three bilingual groups to examine the role of emotion on bilingual language regulation in a cued-language production task. Utilizing a cross-cultural approach, we investigated how that emotion effect may be modulated by interactional context.

1.1. Bilingual Language Regulation

Language regulation in bilingual speakers is one of the most investigated topics in research on bilingualism and cognition. Bilingual speakers must constantly manage dual-language activation in order to comprehend or produce language. The activation of the nontarget language creates competition which is believed to be resolved through mechanisms such as cognitive or inhibitory control (Green, 1998; Declerck & Koch, 2022). One of the most common experimental designs to examine language regulation is cued-language switching production tasks (but see Olson (2017), Bultena, Dijkstra, & Van Hell (2015) or Jiang, Ma, & Chen (2024) for studies on language regulation in comprehension). Bilingual participants are tasked to name pictures (e.g., Misra et al., 2012, Mishra & Asthana, 2026) or numbers (e.g., Jackson et al., 2001) in a target language indicated through visual (e.g., color frames, country flags) or auditory cues (e.g., tones or conversational questions, Timmer, Wolna & Wodniecka, 2025). Pictures are either named in the same language as the preceding trial referred to as stay or language repeated trial, or they named in a different language, referred to as a switch trial. In unbalanced bilingual speakers, an asymmetrical switch cost is observed for the dominant first language (L1) (Meuter & Allport, 1999; Costa & Santesteban, 2004; Misra et al., 2012). Because down regulating the activation of a dominant language requires a significant amount of cognitive effort, reengaging it in the next trial incurs a lag in production. In addition, the scope of this regulation effort is so vast that unbalanced bilinguals experience a reversed language dominance effect (Declerk et al., 2020; Goldrick & Gollan, 2023). In a context where the two languages are used, unbalanced bilinguals may actually appear to perform better in their nondominant second language (L2) than their L1.

Switch costs and reversed dominance effects are not the only behavioral markers used to examine language regulation (see Gode et al., 2021 for a meta-analysis on these effects). Several studies used cued-language picture naming tasks with both pure and mixed language blocks. In the pure language blocks, participants only name pictures in one of their languages (L1 or L2). Critically, the order in which they complete each language block is counterbalanced. Comparing block order conditions, studies have shown that L1 performance is worse when the L2 is done first. For example, Branzi et al. (2014) had highly proficient Catalan-Spanish bilinguals complete a cued-language picture naming task and found that block order affected L1 Catalan naming but not L2 Spanish naming, with slower L1 naming when it followed L2 naming. Block order effects have been explained by the sustained regulation of the dominant L1 in order to produce the L2.

Similarly, the cost of constantly regulating the L1 can be seen when comparing pure language and the stay trials (language repeated) in the mixed language blocks. In both cases, participants are staying in the same language across trials (i.e., L1 → L1 or L2 → L2). However, in the mixed language block, participants are anticipating potential switches which require a certain dual-language activation to be present. On the other hand, in the pure language block, the non-target language can be constantly down regulated. The difference between mixed and pure language blocks is referred to as mixing costs. Using a cued-language picture naming task, Christoffels et al. (2007) found that, for both switch and stay trials, unbalanced German-Dutch bilinguals performed worse in their L1 than in their L2 (reversed dominance effect) in the mixed language and their L1 performance was better when only naming in pure language blocks (mixing cost).

In summary, switch costs, reversed dominance, block order effects and mixing costs have all been used as indexes of language regulation in cued-language naming tasks (see **Error! Reference source not found.** for a visual summary). All of these effects are the consequence of bilingual speakers having to manage the interference of a non-target language in order to produce words in the target language. However, these behavioral indexes, although related, are not interchangeable. Each of them is the result of different contextual demands on language regulation and they are shaped by the cumulative experience bilingual speakers have with regulating their languages. For example, Costa and Santesteban (2004) observed symmetrical switch costs when participants were highly proficient and matched in their two languages. Similarly, studies like Han et al. (2022) and Hernandez-Santa Cruz et al. (2026) found that habitual codeswitching led to reduced switch costs. These mixed findings highlight the need to consider the variation in bilingual contexts and experiences.

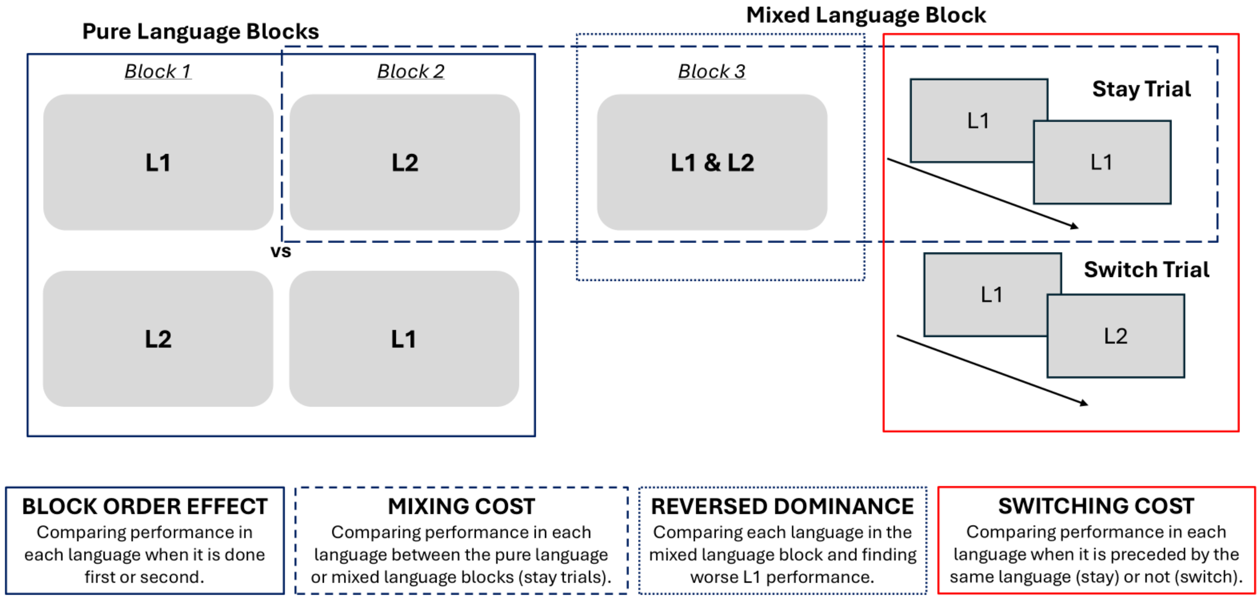


Figure 1.Summary of the Indexes of Language Regulation

Given that bilingual contexts are varied in terms of language use and support, a number of studies have used cross-cultural designs to examine the role of interactional context. Beatty-Martínez et al. (2020) recruited populations of Spanish-English bilinguals in three different locations: Spain, Puerto Rico, and in Pennsylvania, US. They had participants complete a picture naming task as well as the AX-Continuous Performance task (Morales et al., 2013) to measure cognitive control. Their results suggest that bilinguals across these locations engage cognitive control differently to support their languages. Relying on reactive control (acting only after a change happens) was beneficial for bilinguals in Spain but proactive control (acting in anticipation of a change) was beneficial for those in the US when naming pictures in their L1 Spanish. The characteristics of these interactional contexts are crucial in understanding the difference in recruiting cognitive control. In Spain, Spanish is used almost exclusively across different social settings such as home, friends, work, etc. The opportunities to use English are few and limited to specific contexts like school/work. Beatty-Martínez et al. describe this interactional context as 'separated' with both languages rarely mixing and each language ascribed to specific contexts (e.g., home vs work). Bilinguals in the US and in Puerto Rico, on the other hand, are more likely to navigate contexts where both languages are used opportunistically. There is greater support in these two contexts for language switching and mixing. This framing is consistent with the adaptive control hypothesis of Green and Abutalebi (2013) which emphasizes that bilingual control demands vary depending on interactional and contextual requirements.

Interactional contexts can differ by geographical location, but even within the same location, bilinguals may navigate different linguistic contexts. Studies using methods such as language entropy (Gullifer & Titone, 2020) and social network analysis (Tiv et al., 2022) have showcased how, even within a community, bilingual speakers differ in terms of the relative use and exposure to each language across communicative contexts (Gullifer et al., 2018), patterns and frequency of code-switching, and the extent to which bilinguals' everyday language use resembles more compartmentalized single-language or integrated dual-language contexts (Gullifer & Titone, 2020). These studies highlight the need to consider not only between group differences in bilingual speakers but also individual differences within bilingual groups.

1.2. Emotion, Cognition, and Bilingualism

Independent of the bilingualism literature, there is an extensive amount of research on the relationship between emotions and cognition. Emotions are the result of subjective experiences that provoke neurophysiological (e.g., dopamine release, amygdala activation) and behavioral expressions, like smiling or crying (Inzlicht et al., 2015). Emotions help guide our behavior, such as avoiding high stress situations or seeking to increase moments of joy. More importantly, emotions influence cognitive processes such as attention, inhibition, task switching, and conflict monitoring (see Pessoa (2008) for a review). For example, Zinchenko et al. (2015) found that negative stimuli directly influence conflict resolution performance on a Stroop task as evidenced from faster reaction times on incongruent trials. Studies looking at the effects of emotion on memory have found a boost in immediate and delayed recall of emotional content (e.g., negative or positive words, Kensinger & Corkin, 2003; emotional pictures, Wang et al., 2017) over neutral content, and even a spillover of those emotional effects onto following neutral stimuli (Schmidt & Schmidt, 2016). Furthermore, emotions themselves are subject to regulation. Although emotion regulation is not the focus of the present study, it is important to note that it relies partly on cognitive control mechanisms (Pruessner et al., 2020; Agudelo-Orjuela et al., 2021; Hendricks & Buchanan, 2016) that are also recruited during bilingual language regulation (Abutalebi & Green, 2008). This potential overlap provides insights as to how emotional processing may interact with the mechanisms supporting bilingual language regulation.

For bilingual speakers, the influence of emotion on cognition is complex since research on emotion and bilingualism reports asymmetrical emotional processing between the L1 and L2. Bilingual speakers tend to have heightened emotional experiences (Harris, 2004), process emotional content faster and more automatically (Chen et al., 2015), and recall emotional content more accurately (e.g., Weimer & Koniakowsky, 2022) when these occur in their L1. Accounts explaining the stronger L1-emotion relationship have pointed out the privilege of early age of acquisition (e.g., Pavlenko, 2012), naturalistic learning context (Pavlenko, 2005; Pavlenko, 2012), rich social interactions (e.g., Herbert, 2023), and processing speed (e.g., Thoma, 2021). Speakers learn their first language earlier in life under naturally and socially rich environments which results in stronger conceptual links between the L1 system and emotions.

Although most studies report stronger emotional processing in the L1, other studies have found emotional effects in the L2 (e.g., Harris, 2004; Thoma, 2024). Vargas Fuentes et al. (2022) examined Spanish-English heritage speakers' memory of English words with different emotional valences: neutral (e.g., apron), negative (e.g., death), and taboo (e.g., rape). Performance in a surprise recognition test showed an advantage of taboo words over neutral words. This emotion-memory effect was more pronounced for English dominant speakers who used English more frequently and reported higher proficiency and comfort using English. Emotional processing is not necessarily constrained to the L1, but the strength of the language-emotion relationship may be dependent on language experience.

1.3. Emotion and Bilingual Language Regulation

Existing findings suggest that emotional information can influence bilingual language processing (Zhang et al., 2023), but it remains unclear whether emotion alters the control processes involved in switching languages and whether these effects generalize across bilingual populations with different language experiences. Initial evidence comes from the work of Liu et al. (2023) with Mandarin-English bilinguals in China. Participants completed a mixed language picture naming task with an intermixed emotion word classification task. First, participants were shown auditorily presented with an emotion word and tasked to verbally classify the word as either positive or negative in the presented language (e.g., if the positive word was in English, then they said 'Positive' in English). After classifying the word, they were shown a picture with a color cue indicating the target language. In half of the trials the picture was named in the language of the preceding emotion word (stay trial) and, in the other half, it switched. The alternating design of this paradigm follows the logic of prior work examining language and inhibition (Hsu & Novick, 2016) and emotion and inhibition (Agudelo-Orjuela et al., 2021).

Liu et al. (2023) found reduced switch costs after negative words regardless of language direction. Even more, fMRI data suggests that, after processing negative words, cognitive control-related brain regions were more active in non-switch trials compared to switch trials. The opposite was true for positive words. A potential explanation of emotion affecting language regulation is that negative emotions appear to engage cognitive control processes such as inhibition (Inzlicht et al., 2015; Zinchenko et al., 2015; Pruessner et al., 2020), making subsequent switches easier to do. In more recent work, Liu et al. (2026) found similar effects of negative states on language control using electrophysiological data (i.e., EEG) while Liu et al. (2026) found differential effects of negative words for L1 and L2 switching. The emerging evidence strongly suggests an effect of negative emotions in facilitating language switching yet, to our knowledge, no study has focused on how context may mediate this effect.

1.4. Present Study

The present study examines the experience of three distinct bilingual groups to examine the relationship between emotion and bilingual language regulation. Spanish-English late bilinguals from Mexico and two groups of heritage speakers in the US (Spanish and Mandarin) completed a cued-language picture naming task with an emotion manipulation in the mixed language block (paradigm adapted from Liu et al., 2013). Using the picture naming task as well as another language production task (i.e., semantic verbal fluency) and a language questionnaire, we constructed detailed profiles of these bilingual groups and their sensitivity to different indexes of language regulation (i.e., reversed dominance effects, block order effects, and mixing costs). Importantly, these three groups can be characterized and compared along multiple dimensions, including language pair (Spanish-English vs. Mandarin-English), bilingual experience (late vs. heritage bilingualism), and geographical and interactional context. For the present analyses, we compare English with the other language (Spanish or Mandarin), as English is the common language across all three groups. This distinction is analytical rather than a categorization of English as the L2, as English occupies a different status within the language experience of each group and, particularly for heritage bilinguals, cannot be straightforwardly characterized as an L2. We predicted that differences in interactional context and language experience would lead late bilinguals in Mexico to show patterns distinct from the two US heritage groups, because their immersion language and the single- versus dual-language nature of their interactional contexts impose different demands on language regulation.

Lastly, we look into their performance in the mixed language block and ask whether emotional valence (positive vs negative) affected performance in language switching. Given prior work documenting differences in bilingual emotional processing, we expect any observed emotion effect on bilingual regulation to be context-dependent. Particularly, we expected to replicate the effect of negative words on reducing switch costs. Whether the effect of emotion on bilingual regulation differs across interactional contexts is a unique contribution of this study.

2. Participants

We recruited three groups of bilingual speakers from two different locations. The first group were Spanish-English late bilingual speakers from Morelos, Mexico. The second and third group were from Southern California in the US, and they were heritage speakers of Mandarin and Spanish respectively. All participants were recruited from college campuses and their participation monetarily compensated. To participate in this study, participants needed to be able to read, understand, and speak in both of their languages. In addition, for the heritage speakers in Southern California, they must have acquired their heritage language at home and English, the societal language, no later than 12 years of age.

The data of participants who did not meet the inclusion criteria or who experienced technical difficulties during data collection was excluded from final analysis. In Table 1**Error! Reference source not found.** descriptive information is provided for each group as it relates to their language history and self-reported proficiency. Overall, bilinguals in Mexico report higher proficiency across all language aspects (e.g., reading, speaking) in Spanish compared to their English. Meanwhile, the two heritage US groups report higher proficiency in English.

Table 1.Descriptive Information for Each Group.

	Spanish Late Bilinguals (Mexico)	Mandarin Heritage Speakers (US)	Spanish Heritage Speakers (US)
N	34	28	28
Females	21	17	20
Age (yrs.)	24.06 (6.34)	19.54 (1.05)	20.21 (2.44)
English			
Age of Acquisition (yrs.)	8.74 (4.43)	4.43 (3.3)	3.07 (2.37)
Overall Proficiency	18.29 (3.24)	20.79 (3.12)	23.46 (1.09)
Speak	4.5 (0.98)	5.14 (0.83)	5.79 (0.41)
Understand	5.03 (0.75)	5.32 (0.85)	5.93 (0.26)
Write	4.03 (1.27)	5.11 (0.94)	5.82 (0.38)
Read	4.74 (1.34)	5.21 (0.9)	5.93 (0.26)
Other Language			
Age of Acquisition (yrs.)	0.5 (1.82)	0.18 (0.93)	0.36 (1.23)
Overall Proficiency	22.79 (1.6)	19.11 (4.66)	18.64 (3.68)
Speak	5.79 (0.47)	5.14 (1.09)	4.54 (0.98)
Understand	5.88 (0.32)	5.46 (0.78)	5.29 (0.84)
Write	5.56 (0.55)	3.68 (1.95)	4.07 (1.28)
Read	5.56 (1.22)	4.82 (1.56)	4.93 (0.86)

Note: For the measures of age of acquisition and self-rated proficiency, the value shown is mean (standard deviation). The possible range for Overall Proficiency is [0,24] and for each subcomponent (e.g., Read, Write) the range is [0,6]. Self-rated proficiency was gathered through the Bilingual Language Profile Questionnaire.

We administered the Bilingual Language Profile (BLP; Birdsong et al., 2012) to calculate the dominance of each group relative to English and Spanish/Mandarin. The BLP dominance score is a composite score considering participants' self-reported language history (e.g., age of acquisition), language use (e.g., percentage of time using each language), self-reported language proficiency, and language attitude (e.g., how important is each language to their self-identity). The resulting dominance score ranges from [-218, 218] with numbers leaning to either extreme indicating more dominance towards one language, and numbers near zero indicating more balanced dominance. For the purpose of this study, higher scores denote more English dominance and lower scores more dominance towards Spanish or Mandarin. **Error! Reference source not found.** shows the distribution of dominance scores as calculated by the BLP for each group. The late bilinguals from Mexico are more Spanish dominant (*M* = -88.14, *SD* = 38.71, [-160.28, -3.63]). On the other hand, Spanish heritage speakers in the US are more English dominant (*M* = 43.91, *SD* = 29.27, [-29.88, 90.10]) with some participants being more balanced or Spanish dominant. The Mandarin heritage speakers represent the group with the most variability in dominance (*M* = -0.40, *SD* = 59.91) with scores ranging from Mandarin dominant to English dominant [-95.62, 128.86].

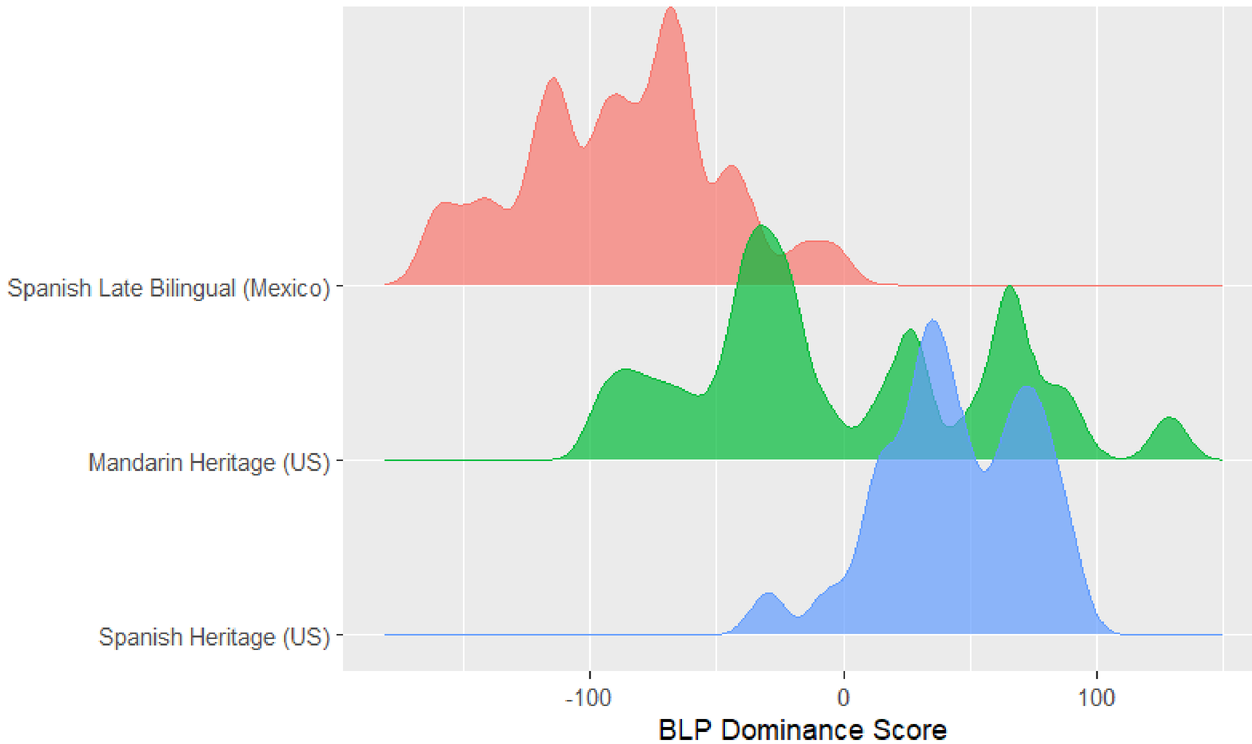


Figure 2.Distribution of Dominance Scores per Group

Note: Higher BLP dominance scores denote more English dominance. Scores closer to 0 are considered more balanced relative to the two languages.

3. Methods

3.1. Verbal Fluency Task

Participants completed a semantic verbal fluency task. A total of 8 semantic categories (e.g., sports, fruits) were presented across two language blocks (4 categories per language). The order presentation of language blocks and the categories for each language block was counterbalanced across participants. Participants had thirty seconds to name as many unique exemplars as possible in each category in the target language. Responses were transcribed, coded, and quality checked by a group of undergraduate research assistants with proficiency in either Mandarin or Spanish and in English. Points were awarded if the participant named a unique appropriate exemplar for the target category and in the target language.

3.2. Picture Naming Task

In the picture naming task, participants were presented with a series of simple black-line drawings depicting objects and were taskedto name the object according to the color of the frame (e.g., red frame = Spanish, blue frame = English). Once participants named the object, the task moved on to the next trial. Each picture was presented for a total of 1500 ms and followed by a fixation cross (300 ms). Participants completed a total of three blocks: one pure language block in English, one pure language block in Spanish/Mandarin, and one mixed language block. Each of the pure language blocks had a total of 40 trials and the mixed language block had a total of 80 trials (40 for each language). A total of 160 pictures were taken from the International Picture Naming Database (Szekely et al., 2004) and divided into four counterbalanced lists controlled for frequency, concreteness and valence for each language (see Appendix A for examples of pictures). We used the English Lexicon Project (Balota et al., 2007) database for the English characteristics, the SANDChild (Sabater et al., 2020) for Spanish, and the timed picture naming norming dataset for Mandarin (Liu et al., 2011). The presentation of the 4 lists was counterbalanced across each block type and target language for a total of 8 task versions of the picture naming task.

Each recorded response was transcribed, coded, and quality checked by undergraduate research assistants that were proficient in either Spanish or Mandarin and English as well. Two rounds of scoring were conducted. For strict scoring, a point was awarded when the response was an exact match or a mispronounced version (e.g., *teeth* instead of *tooth*) of the target word. Target words were chosen according to the target English word from the picture database and their translations taken from the Spanish and Mandarin word databases mentioned above. A second round of scoring was conducted with more lenient parameters. In this case, semantically appropriate words (e.g., response *bonefire,* target word *fire*) and dialectal variations (e.g., *tecolote* is the word for *owl* in some Mexican variations, as opposed to *búho*) were counted as accurate. For the sake of the present study, analyses were based on lenient scoring.

Participants completed a total of 3 blocks. The first two blocks were pure language only and pictures were named entirely in English or in Spanish/Mandarin. The third block was a mixed language block where participants named pictures in both of their languages. Half of the trials in the mixed language block were stay trials, where the picture is named in the same language as the previous trial (e.g., English trial preceded by English trial), and the other half were switch trials (e.g., English trial preceded by Spanish trial). Each pure language block consisted of 40 trials, and the mixed language block had 80 trials. Pictures only appeared once in the task to avoid repetition effects.

3.3. Emotion Word Manipulation

A set of 16 emotion words (8 positive and 8 negative) were selected and controlled for length, age of acquisition, concreteness, familiarity, and emotional valence in each language following the criteria set by Liu et al. (2023). For the Mandarin version, the same words from Liu et al. (2023) were used. However, some words were substituted in the Spanish-English version to account for cognates (See Appendix for the list of words). Repeated-measures ANOVAs confirmed that the positive and negative word lists within each language did not differ other than for valence (see Appendix B for the list of words).

The lists of emotion words were presented in the mixed language block. Before each picture naming trial, participants were tasked with classifying a word as either positive or negative via button press. The word was either in English or Spanish/Mandarin and the following picture trials was either named in the same language as the word (stay trial) or in a different language (switch trial). The mixed language block followed a 2x2x2 factorial design with Emotion (positive vs negative), Language (English vs Spanish/Mandarin), and Switch Condition (stay vs switch trial) as factors.

3.4. Procedure

All tasks were presented using E-Prime (v. 3.0) on a desktop computer. Responses were recorded via a Chronos response button box and a built-in voice key with millisecond-accurate reaction time tracking using a Chronos accessory microphone. Oral responses to the verbal fluency and picture naming task were recorded using an external recording device. Participants were part of a larger project on bilingual variation and its effects on language processing. As such, they completed numerous tasks which are not all detailed in the present study. For the tasks discussed in this publication, all participants completed the Bilingual Language Profile questionnaire at home via google forms and the picture naming and verbal fluency task in person at the lab. The order of the task stayed the same across participants with the verbal fluency task being completed last in the task battery.

3.5. Analysis

Data wrangling and analysis was done in Rstudio (R version 4.6.1; R Core Team, 2026). Data was fitted using generalized linear mixed effect models to predict accuracy (binary outcomes) and linear mixed effect models to predict numerical continuous outcomes (e.g., reaction times) were created using the lme4 (Douglas Bates et al, 2015) and lmerTest (Kuznetsova et al., 2017) package. It is important to note that the factor of Language was structured with two levels (English vs Other Language) to properly compare the three groups regardless of language pair. To examine main effects, type III analysis of variance (ANOVA) were conducted using the ‘car’ package (Fox & Weisberg, 2019). For the generalized linear models, analyses of deviance Type II Wald chi-square tests were conducted using the same *car* package. Post-hoc estimated marginal means analyses were done with 'emmeans' R package (Lenth & Piaskowski, 2026).

Before analyzing the reaction time data of the picture naming task, we followed a set of data cleaning procedures. First, only the reaction time data of correctly named trials were analyzed. Then, we identified outliers as trials with reaction times below 300 ms and above 3000 ms. Lastly, a total of 4 participants (2 from each heritage group) were excluded due to technical issues and substantial data loss after data cleaning. Although their reaction time data was not used, their oral responses were recorded and properly coded for accuracy. Therefore, their data is included in the verbal fluency and picture naming accuracy analysis.

4. Results

4.1. Verbal Fluency

Error! Reference source not found. shows the average number of unique exemplars made across all categories for each group by the target language and the language order. We fitted a linear mixed-effects model to examine the effect of fixed factors 'Language', 'Language Order' and 'Group' on the total score in the verbal fluency task, including a random intercept for participants. Type III Analysis of Variance (ANOVA) with Satterthwaite's approximation for degrees of freedom revealed a significant main effect of Group, $F(1, 81) = 11.04$, $p < 0.001$, an interaction between Language and Group, $F(2, 81) = 28.02$, $p < 0.001$, and between Language and Language Order, $F(1, 81) = 6.67$, $p = 0.01$.

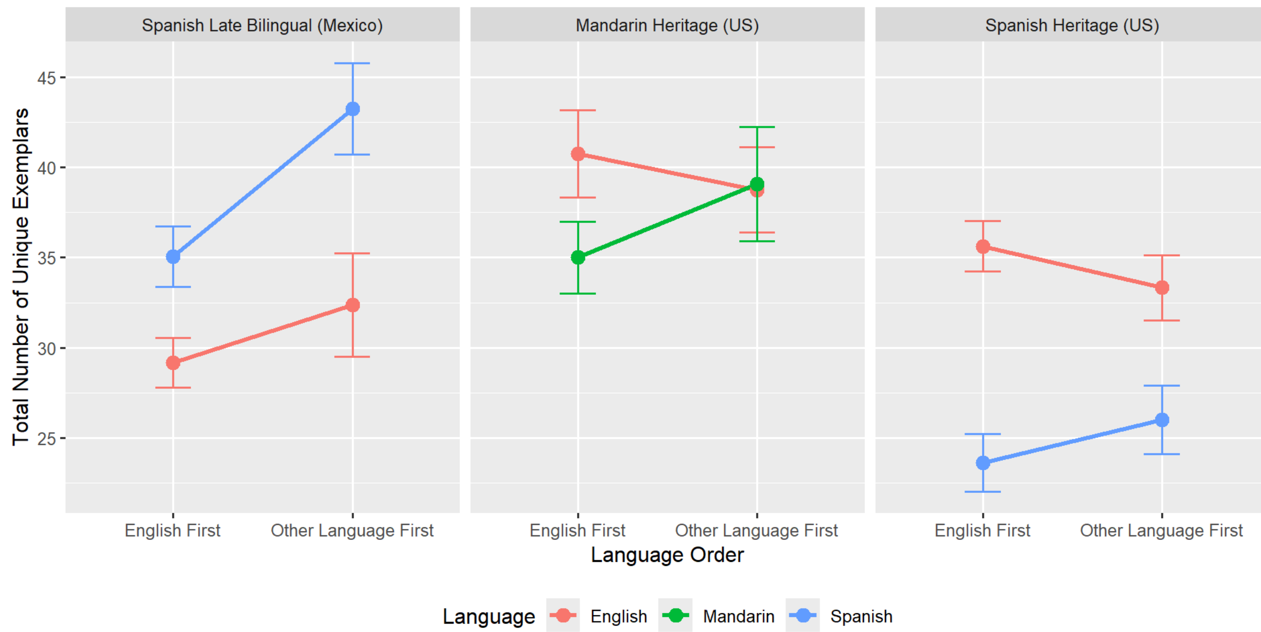


Figure 3.Verbal Fluency Score by each Language, Language Order, and Group

Note: The center point represents the mean score, and the error bars represent one +/- standard deviations from the mean. For the Language Order (x axis), other language is Spanish for the Spanish Late Bilingual (Mexico) and the Spanish Heritage (US) group. For the Mandarin Heritage (US) group, other language is Mandarin.

To examine the two-way interactions, we conducted estimated marginal means analyses adjusted via the Bonferroni method. The post-hoc analyses revealed that language differences were significant for the Spanish late bilinguals in Mexico and for the Spanish heritage speakers in the US but not for the Mandarin heritage speakers ($\Delta M = 2.71, SE = 1.79,\ t(81) = 1.517, p = 0.13$). The late bilinguals in Mexico performed better in Spanish than in English ($\Delta M = -8.38, SE = 1.61,\ t(81) = -5.22, p < 0.001$) and the opposite was true for the US Spanish heritage speakers ($\Delta M = 9.67, SE = 1.87,\ t(81) = 5.16, p < 0.001$). Their performance in the verbal fluency task aligns with the overall dominance profile captured by the BLP questionnaire; bilinguals in Mexico are more Spanish dominant, Spanish heritage speakers in the US are more English dominant, and Mandarin heritage speakers fall somewhere in between—leaning more towards balanced dominance.

The estimated marginal means analysis for the Language and Language Order interaction showed a significant boost for Spanish/Mandarin (other language) when it is done first instead of second ($\Delta M = -4.89, SE = 1.79,\ t(144) = -2.74, p = 0.007$). The same is not true for English ($\Delta M = 0.34, SE = 1.79,\ t(144) = 0.20, p = 0.84$). It is important to note that the model did not yield a significant three-way interaction between Group, Language and Language Order ($F(2, 81) = 0.04$, $p = 0.96$) which implies that the boost of the other language due to language order is independent of group. This finding contradicts past work on order effects on the dominant language since Spanish is not the dominant language of the Spanish heritage group. Meanwhile, the Mandarin heritage group is more balanced, and we would expect to find a boost for both languages.

Overall, the verbal fluency scores show a distinct pattern of language dominance and sensitivity to language order effects which are indicators of language control. The late bilinguals in Mexico are more Spanish dominant and show greater sensitivity to order effects in their dominant language, Spanish. On the other extreme of the dominance scale, Spanish heritage speakers in the US are more English dominant while Mandarin heritage speakers figure somewhere in between with more inclination towards balanced. Although different in terms of dominance, both groups of heritage speakers showed order effects in their non-English language. This marks an important distinction of how heritage speakers engage language control to support their heritage language.

4.2. Picture Naming Task

Accuracy

In this section, we report on the accuracy performance in the picture naming task. We fitted a generalized linear mixed effect model predicting lenient scoring by Group, Language, and Block Condition as fixed effects with participants as random intercepts. For the sake of capturing the different indexes of language control (i.e., block order effects and mixing costs), we structured the variable of Block to have three levels: Pure Language (English First), Pure Language (Other First), and Mixed Block. In the mixed block level, we only consider stay trials since they reflect the most well-matched counterpart to pure language block trials.

A type III Wald chi-square test showed a main effect of Group ($X^2(2) = 85.05, p < 0.001$) and a main effect of Language ($X^2(1) = 111.20, p < 0.001$), but no main effect of Block ($X^2(2) = 2.77, p = 0.25$). The model also yielded statistically significant interactions: a two-way interaction between Group and Language ($X^2(2) = 220.33, p < 0.001$), a two-way interaction between Language and Block ($X^2(2) = 12.68, p = 0.002$), and a three-way interaction between all the fixed factors ($X^2(4) = 21.60, p < 0.001$). Given the presence of an interaction with all factors, we focus our analysis on understanding these differences instead of the main effects or two-way interactions. With that aim, we calculated estimated marginal means as a post-hoc analysis. We focused on understanding how the interaction between Language and Block differed within each group. Estimates were transformed from the logit scale to the response scale and are reported as predicted probabilities. Pairwise comparisons were conducted and adjusted via the Bonferroni method for multiple comparisons (see Appendix C).

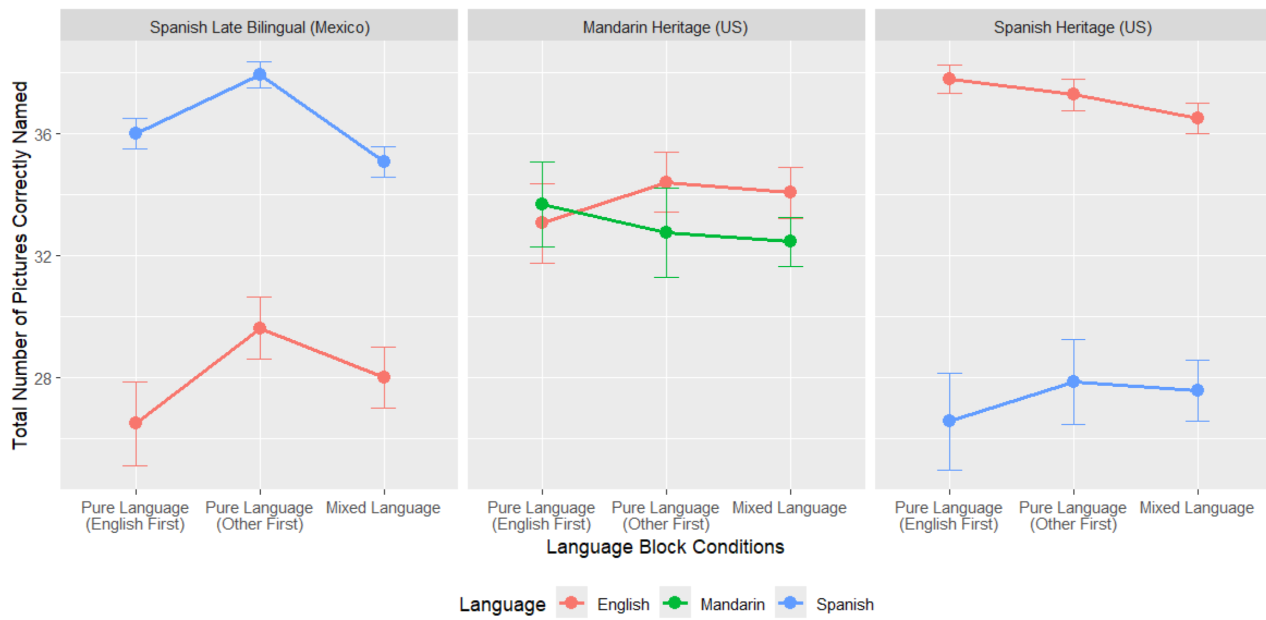


Figure 4. Picture Naming Accuracy by each Language, Block, and Group

Note: The center point represents the mean score, and the error bars represent one +/- standard deviations from the mean. For Language Block Condition (x axis), other language is Spanish for the Spanish Late Bilingual (Mexico) and the Spanish Heritage (US) group. For the Mandarin Heritage (US) group, other language is Mandarin.

For the Spanish late bilinguals in Mexico, there were significant differences in language performance across all language block conditions. They were more accurate naming pictures in Spanish than English both when English was named first (odds ratio = 0.21, SE = 0.03, z = -10.55, p <0.001) and when Spanish was named first (odds ratio = 0.15, SE = 0.03, z = -9.41, p < 0.001). Likewise, accuracy in Spanish was superior in the mixed language condition (odds ratio = 0.31, SE = 0.03, z = -11.29, p < 0.001). In terms of language block effects, there was no difference in the effect of pure versus mixed language condition nor order effect for English naming accuracy. That is, doing English first, Spanish first, or both in the same block did not differentially affect English. On the other hand, naming accuracy in Spanish was significantly affected by block type. Late bilinguals in Mexico had higher accuracy naming pictures in

Spanish when Spanish was named first (odds ratio = 0.57, SE = 0.13, z = -2.43, p = 0.046) in the pure language block. They also experienced mixing cost; picture naming accuracy is estimated to be higher in the pure language condition than in the mixed language condition. This effect is evident when we compared performance in the mixed language condition (stay trials only) to the pure language (Spanish first) condition (odds ratio = 2.39, SE = 0.49, z = 4.27, $p < 0.001$) but not when compared to the pure language (English first) condition (odds ratio = 1.35, SE = 0.21, z = 1.92, p = 0.16).

The US Spanish heritage group presents a contrasting image to their Mexican Spanish late bilingual counterparts. Across all three block language conditions, US Spanish heritage speakers were more likely to correctly name more pictures in English than in Spanish: pure language (English First): odds ratio = 9.23, SE = 1.92, z = 10.67, $p < 0.001$; pure language (Other First): odds ratio = 6.14, SE = 1.18, z = 9.41, $p < 0.001$; mixed language (stay trials): odds ratio = 4.94, SE = 0.62, z = 12.70, $p < 0.001$. In terms of language regulation, US Spanish heritage speakers experienced a mixing cost for English but no order effects for either language. Our model analysis shows no difference between naming pictures in English or Spanish first (English, odds ratio = 1.37, SE = 0.37, z = 1.16, p = 0.74; Spanish, odds ratio = 0.91, SE = 0.15, z = -0.6, p = 1.00). However, naming accuracy for English was statistically higher in the pure language (English first) condition than in the mixed language condition (odds ratio = 1.71, SE = 0.38, z = 2.43, p = 0.046).

In contrast with the distinct language dominance profiles of the other two groups, the Mandarin heritage group showed significant language differences only in the mixed language condition. When naming pictures in both languages, Mandarin heritage speakers showed higher accuracy in English (odds ratio = 1.34, SE = 0.15, z = 2.57, p = 0.01). However, regardless of the order of the pure language blocks, there was no significant difference in the accuracy of English and Mandarin; pure language (English First), odds ratio = 0.89, $SE = 0.14$, $z = -0.76$, $p = 0.45$), pure language (Other First), odds ratio = 1.38, $SE = 0.25$, $z = 1.78$, $p = 0.07$. Regarding our measures of language regulation (order effects and mixing costs), there was no interaction between language and block condition for the Mandarin heritage group.

In summary, looking at accuracy in the picture naming task, we found the same pattern of language dominance for each group. Mexico bilinguals are Spanish dominant, Mandarin heritage speakers are more balanced, and Spanish heritage speakers are more English dominant. Also converging with the verbal fluency data, two groups showed sensitivity to language regulation indexes. The late bilinguals in Mexico showed both order effects and mixing cost in their performance of Spanish, their dominant language. Meanwhile, the US Spanish heritage group showed only mixing costs for their dominant language, English, but no order effects. The differences of sensitivity towards indexes of language regulation provide a more nuanced image of how the interaction context of each group shapes how they manage their two languages.

Reaction Time

We fitted a linear mixed effect model to examine reaction time in the pure language blocks of the picture naming task with Group, Language, and Language Order as fixed factors and participants as random intercepts. A Type III Analysis of Variance (ANOVA) with Satterthwaite's approximation for degrees of freedom revealed a significant main effect of Language ($F(1, 4151.7) = 50.42$, $p < 0.001$), Block ($F(2, 7639.4) = 587.82$, $p < 0.001$), and Group ($F(2, 80.4) = 2.15$, $p < 0.001$). The model analysis also showed significant two-way interactions and a three-way interaction ($F(4, 8055.3) = 11.61$, $p < 0.001$). As a post-hoc analysis, we focused on the three-way interaction to understand how language and block condition interact within each group.

Looking at language differences across block conditions for the late bilinguals in Mexico, we find the expected dominance effects. Bilinguals in Mexico were faster at naming pictures in Spanish when Spanish was completed first ($\Delta M = 135.5,\ SE = 28.8, z = 4.71, p < 0.001$). However, when naming pictures in English first, there is no significant difference in how fast late bilinguals in Mexico named pictures in Spanish and English ($\Delta M = 53.2,\ SE = 28.7, z = 1.86, p = 0.06$). The lack of differences between the two languages when the nondominant language, English, is completed first, aligns with reversed dominance effects. Furthermore, this reversed dominance effect is even more pronounced in the mixed language condition where Spanish naming is, on average, slower than English naming ($\Delta M = -111.9, SE = 20.9, z = -5.36, p =$ 0.004).

To a lesser degree, we also see some indications of reversed dominance effects for the US Spanish heritage group. Across all three block conditions, this group of heritage speakers named pictures in English significantly faster than in Spanish. The greatest difference between languages was found in the pure language (English first) condition ($\Delta M = -260.3, SE = 44.6, z = -5.98, p < 0.001$), then in the other pure language (Spanish first) condition ($\Delta M = -139.5, SE = 39.1, z = -3.57, p = 0.004$), and lastly in the mixed language condition ($\Delta M = -67.9, SE = 30.0, z = -2.26, p = 0.02$). Although not completely reversed as was the case for the Mexico group, the small gap between the languages in the mixed condition is indicative of a reversed dominance effect.

Regarding the Mandarin heritage group, the reaction time data captures language differences that accuracy in the picture naming task and the verbal fluency task did not show.

Mandarin heritage speakers (US) were overall faster at naming pictures in English than in Mandarin in all the language blocks. The differences between the two languages were comparable across conditions; pure language (English first) condition ($\Delta M = -174.9, SE = 29.3, z = -5.98, p < 0.001$), pure language (Mandarin first) condition ($\Delta M = -151.0, SE = 39.0, z = -4.20, p < 0.001$), and mixed language condition ($\Delta M = -204.4, SE = 23.7, z = -8.63, p < 0.001$).

In terms of mixing costs (pure vs mixed), all groups showed overall slower reaction times in the mixed language block. This mixing cost was present for both the English and non-English language for all groups. Differences across groups and languages emerge when considering order effects in the pure language blocks. For the late bilingual Mexico group, order effects were seen for both Spanish and English picture naming. Overall, naming pictures in Spanish first provides a boost in speed for both Spanish trials ($\Delta M = 181.4, SE = 32.9, z = 5.51, p < 0.001$) and English trials ($\Delta M = 99.1, SE = 36.9, z = 2.69, p = 0.02$). In contrast, order effects were only present when naming pictures in English for the US Spanish heritage group. They were faster naming pictures in English when English was done first ($\Delta M = -153.6, SE = 47.3, z = -3.25, p = 0.004$). There were no order effects for the Mandarin heritage group.

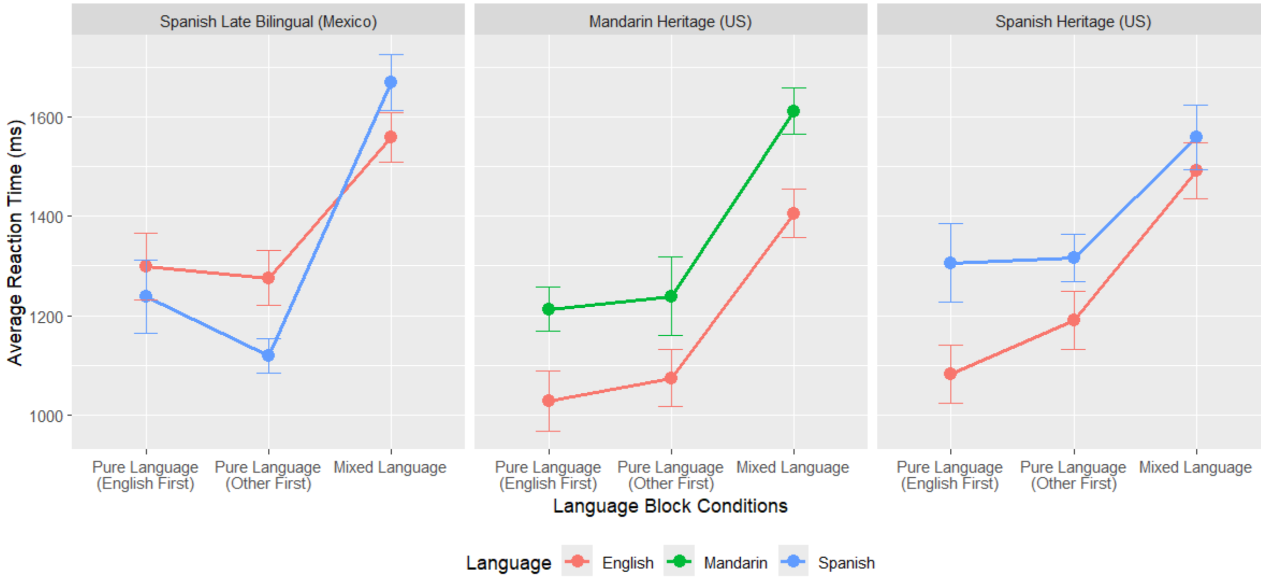


Figure 5. Picture Naming Reaction Time by each Language, Block, and Group

Note: The center point represents the mean reaction time, and the error bars represent one +/- one standard deviation from the mean. For Language Block Condition (x axis), other language is Spanish for the Spanish Late Bilingual (Mexico) and the Spanish Heritage (US) group. For the Mandarin Heritage (US) group, other language is Mandarin.

Overall, reaction time data provides a more sensitive measure for language dominance effects and language regulation. While we still observe a clear Spanish dominance for the Mexico group and an English dominance for the US Spanish heritage group, we now also observe an English dominance to the otherwise balanced Mandarin heritage group. In addition to language differences, the late bilinguals in Mexico experienced a reversed dominance effect where naming in Spanish was significantly slower when in the Mixed condition. This reversed dominance is less pronounced in the US Spanish heritage group where there are no differences between naming in the dominant language, English, and the nondominant heritage language, Spanish. When it comes to the other language regulation indexes, all groups experienced mixing costs for both languages. Order effects, on the other hand, were more clearly seen in the Mexico group, slightly in the US Spanish heritage group and not at all in the Mandarin Group.

4.3. Emotional Word Classification

Across both languages, each group had over 95% overall accuracy in the emotion word classification task. Given the high rate of success, we focus our analysis on the reaction time data. Before the analysis, we eliminated any trials above or below 2.5 standard deviations away from the overall mean in the emotion word classification task. We fitted a linear mixed effect model to predict reaction time in the emotion word classification task. We included Group, Emotional Valence (Positive vs Negative), and Language as fixed effects and included participants as random slopes. A Type III Analysis of Variance (ANOVA) with Satterthwaite's approximation for degrees of freedom revealed a significant a main effect of Emotional Valence ($F(1, 6540.8) = 15.13$, $p < 0.001$) and Language ($F(1, 6541.4) = 13.28$, $p < 0.001$) as well as a main interaction between Group and Emotional Valence ($F(2, 6540.8) = 4.07$, $p = 0.02$).

Pairwise comparisons on estimated means showed that, overall, participants were faster in classifying positive words over negative words ($\Delta M = 37.5, SE = 9.65, z = 3.89, p < 0.001$). English words were also classified faster ($\Delta M = -35.2, SE = 9.65, z = -3.64, p = 0.003$) than Spanish/Mandarin words but this effect was localized in the US Spanish ($\Delta M = -40.6, SE = 17.0, z = -2.39, p = 0.02$) and Mandarin heritage speaker groups ($\Delta M = -50.4, SE = 17.4, z = -2.90, p = 0.004$). Interestingly, the late bilinguals in Mexico did not show a difference in their languages ($\Delta M = -14.5, SE = 15.8, z = -0.92, p = 0.37$) which contradicts our predictions based on previous literature.

4.4. Emotion Effects in Picture Naming Task

Reaction times were analyzed using linear mixed-effect models with participants as random slopes. We constructed a series of theory-driven candidate models with the following fixed effects: Group, Language, Switch Condition (Yes/Switch vs No/Stay), Emotional Valence of the preceding trial (positive vs negative), and standardized reaction time on the preceding emotion word classification trial (referred to in the text as Emotion RT). This last effect was added as an indicator of depth of emotional processing. Fixed-effects structures were evaluated hierarchically, beginning with main effects and subsequently adding theoretically motivated two-way and three-way interactions such as Group x Language, Group x Language x Switch, Switch x Emotional Valence, among others. In Appendix D, we detail the structures and results of all candidate models.

Model fit was evaluated using likelihood-ratio tests and information criteria (AIC and BIC). The final model was subsequently refit using restricted maximum likelihood for parameter estimation. In this section, we present the findings of the final model which included all main effects and an interaction between Group and Language. A type III analysis of variance showed a main effect of Language ($F(1,3559.8) = 63.57$, $p < 0.001$), of Emotional Valence ($F(1,3551.9) = 4.63$, $p = 0.03$), and of Emotion RT ($F(1, 3578.2) = 20.63$, $p < 0.001$). The model also showed a statistically significant interaction between Group and Language ($F(2, 3558.9) = 7.65$, $p < 0.001$). Given the research questions of the present study, it is important to note that there was no significant main effect or interaction with Switching (**Error! Reference source not found.**).

Through pairwise comparison of estimated means, we found that participants tended to name pictures slower after seeing a negative word than a positive word ($\Delta M = 31.7, SE = 14.7, z = 2.15, p = 0.03$) regardless of whether they were switching or staying in the same language. Analysis of the interaction between Language and Group showed similar language differences as found in the former picture naming reaction time analysis (**Error! Reference source not found.**). Late bilinguals in Mexico were overall faster at naming pictures in English regardless of Switch condition and Emotional Valence ($\Delta M = -109.5, SE = 22.4, z = -4.90, p < 0.001$). Although Spanish dominant, this reversed dominance of being faster in English is due to the demands of a mixed language context. The Mandarin heritage group was once again faster at naming pictures in English than Mandarin ($\Delta M = 31.7, SE = 14.7, z = 2.15, p = 0.03$). Interestingly, the US Spanish heritage group did not show a difference in naming pictures in Spanish or in English ($\Delta M = -54.6, SE = 31.6, z = -1.73, p = 0.08$). This can be interpreted as less pronounced reversed dominance effect to their dominant language, English, when completing a mixed language block. Lastly, post hoc analysis on the main effect of Emotion RT showed that longer reaction times in the preceding emotion word trial was associated with longer naming latencies in the picture naming trial. That is, the longer participants took in classifying the emotion word as either positive or negative, the longer it took them to name the picture that followed.

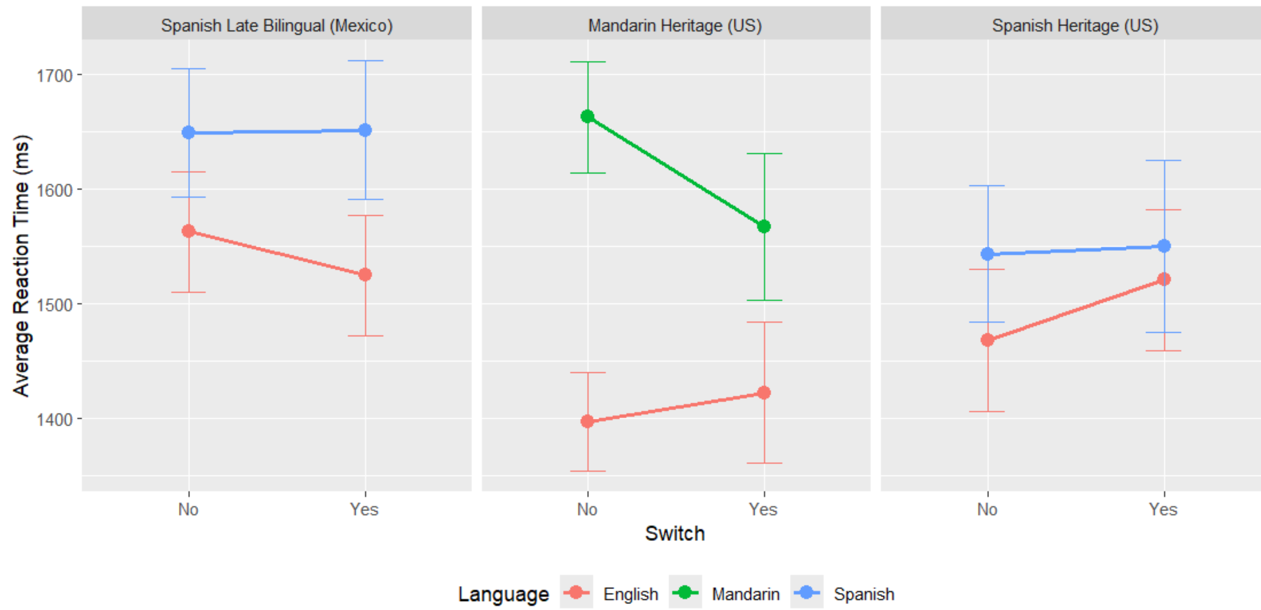


Figure 6. Picture Naming (Mixed Language Block) Reaction Time by Language, Switch, and Group

Note: The center point represents the mean reaction time, and the error bars represent one +/- standard deviations from the mean.

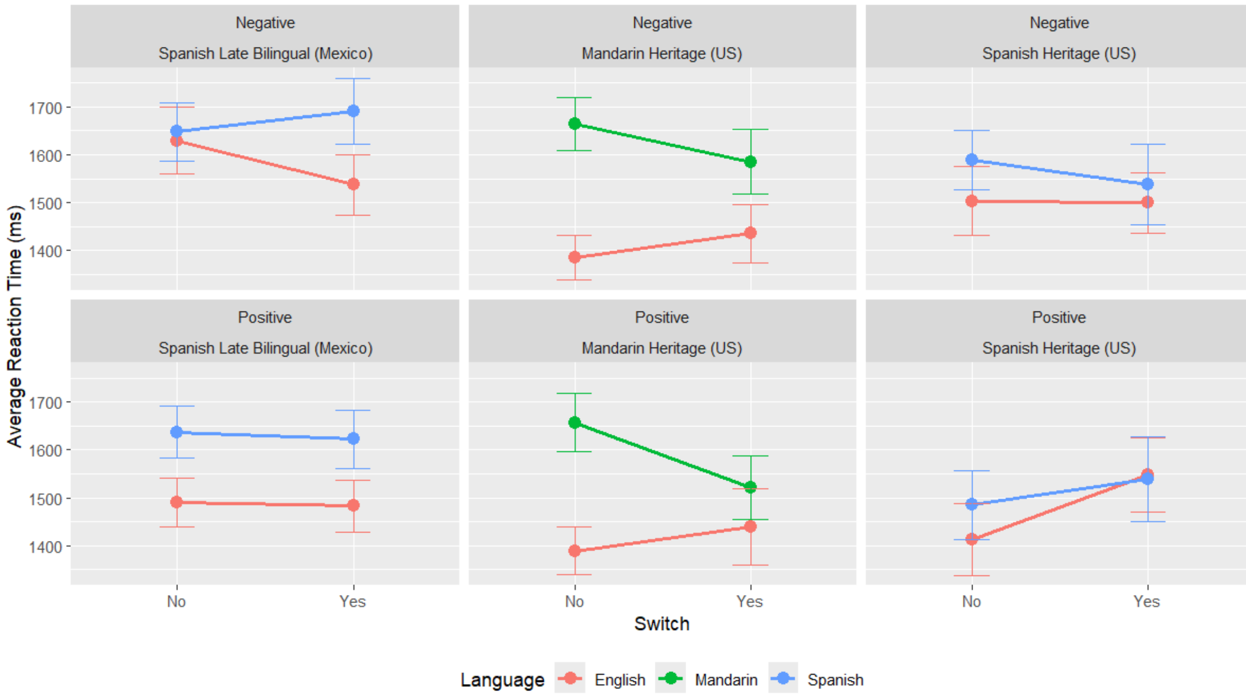


Figure 7. Picture Naming (Mixed Language Block) Reaction Time by Language, Switch, Emotional Valence, and Group

Note: The center point represents the mean reaction time, and the error bars represent one +/- standard deviations from the mean.

5. Discussion

In the present study, we recruited three groups of bilingual speakers from distinct interactional contexts to examine the relationship between emotion and language regulation. In particular, we asked how emotion affects bilingual language regulation in a cued-language switching picture naming task. Our findings suggest that, while these three groups show different sensitivity to contextual demands to language regulation, the observed emotion effects do not differ across groups. Although there was no effect of emotion words on language switching, an effect was observed on overall performance in the picture naming task. Negative words and longer reaction times in the emotion word classification task predicted slower reaction times in picture naming trials. We proceed to discuss these findings considering prior work on interactional context, language regulation, and emotional processing in bilingual speakers.

5.1. Interactional Context and Language Control

To better understand how these three bilingual groups differ in terms of their language dominance and language regulation, we triangulated the data from the language history questionnaire, the verbal fluency, and the picture naming task. Table 2 shows a summary of the findings of each group in terms of language dominance and three indexes of language regulation, reversed dominance effect, order effects, and mixing costs.

5.1.1. Spanish Late Bilinguals (Mexico)

Starting with the Spanish late bilinguals in Mexico, we observed strong patterns of Spanish dominance both in their self-reported data and in their performance in the language production tasks. The Mexican bilingual speakers produced more words in Spanish in the verbal fluency task and were overall more accurate and faster at naming pictures in Spanish in the picture naming task. Furthermore, they experienced the strongest reversed dominance effect, evidently seen by their slower reaction in the mixed language condition. When naming pictures in a context where they may use either language (mixed language context), bilinguals in Mexico named pictures faster in English, their nondominant language. Reversed dominance effects are a sign of language control being strongly exerted to down regulate the dominant language. Such exertion results in a production lag in speed of naming when the previously regulated language (i.e., Spanish) is reengaged. This reversed dominance effect has been documented in other late bilinguals with similar interactional contexts as Mexico (Beatty-Martínez et al., 2020) where languages are rarely intermixed.

Related to the reversed dominance effects are the order effects and mixing cost observed in the language tasks. In the verbal fluency, late bilinguals in Mexico produced more words in Spanish when they completed the first block in Spanish. The same was found for the picture naming task. Naming pictures in Spanish first induced a boost not only to their accuracy but also to their speed in both Spanish and English. Misra et al. (2012) found a facilitation effect for the L2 after naming in L1 for Chinese-English bilinguals in China performing a picture naming task. Although the pictures were repeated in each language block, there was no facilitation effect for the L1 after naming first in the L2. Similar to our sample of Mexican late bilinguals, completing the task in a non-dominant L1 incurred a huge demand to language regulation which consequently affected L1 and L2 production. The amount of cognitive effort endured when regulating a dominant language causes delays when it needs to be used in the subsequent language block. Our findings, in line with the Misra et al. study, suggest that regulation effort affects both L1 and L2 naming. Also, in line with previous findings (e.g., Christoffels et al., 2007) looking at L1-immersed late bilinguals, bilinguals in Mexico experienced a mixing cost to their L1 Spanish and L2 English when naming pictures in a mixed language context. Mixing costs were more pronounced for Spanish which is related to the reversed dominance effect.

Overall, the behavioral results of the Mexico group in the language production tasks pattern with prior work with unbalanced bilingual speakers in a separated language context. The linguistic environment in Mexico is almost exclusively in Spanish, with English used in limited separate contexts. Compared to our US heritage groups, the Spanish-English bilinguals in Mexico have limited experience down regulating their dominant language. This limited experience results in strong sensitivity to the contextual demands in the tasks such as naming in their nondominant L2 first or mixing languages.

5.1.2. Spanish Heritage Speakers (US)

On the other side of dominance, US Spanish heritage speakers consistently performed better in English trials both for the verbal fluency and the picture naming task. They showed subtle signs of reversed dominance effects when naming pictures in the mixed language condition. Although generally faster at naming pictures in English, in the mixed language block, US Spanish heritage speakers did not show a significant difference between their languages. The lack of difference between English and Spanish naming is mainly due to English slowing down in the mixed language task. Gavino et al. (2026) also found a reversed dominance effect for the dominant language, English, when Spanish-English bilinguals in Southern California completed a mixed language picture naming task. Although not described as heritage speakers, these Spanish-English bilinguals reported higher dominance in English and their reaction time in the picture naming task showed such English dominance. This reversed dominance effect in the mixed language block is related to the observed mixing costs for this group. US Spanish heritage speakers were more accurate naming in English in the single language context than the mixed language one. This mixing costs in accuracy was not observed in the case of Spanish naming. When looking at reaction data, we saw an overall mixing costs across all groups. Naming pictures in the mixed language block incurred costs to speed for all languages.

For the US Spanish heritage group, we found block order effects in both the verbal fluency and the picture naming task but not in the same manner. When naming pictures in English, Spanish heritage speakers that named in English first had faster reaction times compared to those who named in English second. Contrary to the Mexico group, this effect was only observed in the reaction time analysis and not in accuracy. Naming in English first did not increase the likelihood of correctly naming pictures in English, only in how fast the lexical items were retrieved. Hernández Santa Cruz et al. (2026) tested a similar group of Spanish heritage speakers in a picture naming task and also found block order effects for reaction time in the societal language, English. Detecting effects in reaction time data but not accuracy is not uncommon in the literature, especially when bilinguals perform at ceiling levels of accuracy or do not have enough variation to find effects (Garcia et al., 2021).

Interestingly, the block order effect found in the verbal fluency task was in relation to the heritage language, Spanish. Completing the first verbal fluency block in Spanish was associated with better Spanish performance. To better understand these Spanish vs English block order effects, we need to consider the characteristics of each analysis. The verbal fluency analysis is done on overall total scores, not on a trial-to-trial basis as is with the picture naming analysis. Given that these speakers are English dominant, the resting lexical activation is relatively high compared to Spanish, the weaker language (Grainger et al., 2010). English is more readily available than Spanish. English, as the dominant language with high resting activation and constant environmental reinforcement, rebounds from any suppression far more rapidly than Spanish does, making any order effects functionally undetectable across cumulative scores. Meanwhile, Spanish resting lexical activation is lower and requires more cognitive effort to reach retrieval thresholds. Doing Spanish second after English requires managing the residual high activation of a previously used dominant language, which places extra cognitive burden specifically on the weaker language retrieval system. The difference in resting lexical activation, managing residual activation from one block to the next, and an analysis on overall cumulative scores instead of trial-by-trial accuracy or reaction time may explain why we see no block order effect in the dominant language, English, but do in Spanish.

Considering performance across the verbal fluency and picture-naming tasks, a distinct profile of language dominance and regulation emerges for the US Spanish heritage group. Whereas the Mexico group represents a context in which the societal environment predominantly supports one language, US Spanish heritage speakers navigate a more varied interactional context in which both languages are used and opportunities for language mixing are more frequent. Nevertheless, English is the dominant language across most settings. Consistent with the BLP questionnaire data, lifelong immersion in English appears to have produced a dominance shift from the first-acquired heritage language, Spanish, to the societal language (Vargas Fuentes et al., 2022). This dominance profile may explain why the demands of language regulation were most apparent in English.

Importantly, however, the US Spanish heritage group was not simply a mirror image of the Mexico group. In picture naming, the Mexico group showed order effects in both accuracy and response speed for its dominant language, whereas US Spanish heritage speakers showed an order effect only in response speed for their dominant language, English. Moreover, in verbal fluency, US Spanish heritage speakers showed an order effect for Spanish: producing Spanish first was associated with higher verbal-fluency scores. We propose that these differences reflect variation in the relative resting activation of the two languages. Although English is used more frequently by US Spanish heritage speakers, Spanish remains supported through regular opportunities for use. Consequently, the resting activation of their nondominant Spanish may be higher than that of English for the Mexico bilinguals, whose interactional context provides fewer opportunities for English use. If the regulatory demands associated with language order depend partly on the amount of control required to manage differences in language activation, this asymmetry could explain why the US Spanish heritage group exhibits a different pattern of order effects from the more strongly unbalanced Mexico group.

5.1.3. Mandarin Heritage Speakers (US)

Lastly, the dominance profile for the Mandarin heritage group is seemingly more balanced, with the least strong dominance for either language across all groups. Similar to their language dominance scores in the Bilingual Language Profile questionnaire, Mandarin heritage speakers showed similar performance across their two languages when producing words (verbal fluency task) or when naming pictures. There seems to be, however, a cost to this balance since, overall, they also produced less words and named fewer pictures compared to the other two groups' performance in their respective dominant language. This trade-off of language dominance and production is similar to those documented between bilingual and monolingual children (Bialystok & Viswanathan, 2009; Oller et al., 2007). In a 2009 study, Bialystok and Viswanathan compared the performance of two groups of bilinguals and a group of monolingual children in a receptive vocabulary test as well as tests of executive functioning. Bilingual children outperformed their monolingual counterparts in the cognitive tasks but had lower scores in the vocabulary test for their first language, English. Since bilingual children navigate two language systems, they may not activate L1 lexical items as frequently or to the same degree as children with only one language system. We propose that this effect of relative frequency of language use and its effects on resting language activation may also account for differences between our more balanced Mandarin group and the more unbalanced Spanish heritage speaker group. Since the Mandarin heritage speakers are using their two languages more equally than the other groups, we see balanced performance within the group's two language but also lower overall performance of

English, the language of the environment, compared to the other heritage group in the picture naming task.

Language differences were found in the analysis of reaction time data and in the accuracy in the mixed language block for this group of heritage speakers. Overall, they were faster at naming pictures in English than in Mandarin across all language block conditions and were more likely to name more pictures in English when mixing languages. Once again, it is not unusual to capture significant differences in reaction times and not in accuracy given the more varied and nuanced measure of the former. It is also not surprising that, when we do see a language difference, dominance inclines towards English, the dominant language in the US context. An important caveat is that the higher accuracy in English in the mixed language block is not the same as mixing costs. Mixing cost are defined as the hit to a language, usually the dominant language, when having to use it in a mixed language context in comparison to a one-language context. Like the other groups in our study, Mandarin heritage speakers showed mixing costs to their naming speed. Contrary to other groups, Mandarin heritage speakers experienced mixing cost to the same extent in both of their languages. Other studies have found similar mixing costs for L1 and L2 naming (e.g., Declerck et al., 2013). van den Berg et al. (2022) found that higher diversity of language use, as measured by language entropy, was associated with reduced mixing costs in a color-shape switching task. A higher diversity of use would also explain the more balanced dominance scores in this group.

Although both the Spanish heritage and Mandarin heritage groups were recruited from the same geographical location (Southern California), they presented distinct language dominance and regulation profiles. Spanish heritage speakers showed stronger English dominance across both tasks and indexes of language regulation, while the Mandarin heritage speakers showed more balanced dominance with moments of inclinations towards English dominance. The different sensitivities to the language regulation indexes reveal differences in the interactional contexts of these two groups, especially as it relates to their experience with the heritage language. Potential differences include formal schooling in the heritage language, biliteracy, codeswitching habits, generational status, among others. An important finding of this study is that geographical location does not always equal different interactional contexts. The heritage speaker experience, as well as other bilingual experiences, is not a homogeneous one.

Table 2. Summary of Results on Language Dominance and Indexes of Language Regulation

	Spanish Late Bilinguals (Mexico)	Mandarin Heritage Speakers (US)	Spanish Heritage Speakers (US)
Language Dominance			
BLP Questionnaire	• More Spanish dominance.	• More balanced but great variation.	• More English dominance.
Verbal Fluency	• Produced more words in Spanish than English.	• No language differences.	• Produced more words in English than Spanish.
Picture Naming	• (*Accuracy*) Better at naming pictures in Spanish than English across all block conditions.	• (*Accuracy*) Better at naming pictures in English only in the mixed language block.	• (*Accuracy*) Better at naming pictures in English than Spanish across all block conditions.
	• (*Reaction Time*) Faster at naming pictures in Spanish but when Spanish came first.	• (*Reaction Time*) Faster at naming pictures in English across all language blocks.	• (*Reaction Time*) Faster at naming pictures in English across all language blocks.
Reversed Dominance effect			
Picture naming	• Spanish naming was slower when Spanish was named second and in the mixed language condition.	• Not observed.	• The difference between English and Spanish becomes less pronounced in the

			mixed language condition.
Order effects			
Verbal Fluency	• Produced more words in Spanish when Spanish was done first.	• Produced more words in Mandarin when Mandarin was done first.	• Produced more words in Spanish when Spanish was done first.
Picture Naming	• (*Accuracy*) Named more pictures in Spanish when Spanish was named first. • (*Reaction Time*) Overall naming was faster when Spanish was done first.	• (*Accuracy*) No order effects observed. • (Reaction *Time*) No order effects observed.	• (*Accuracy*) No order effects. • (*Reaction Time*) Faster naming in English when English was done first.
Mixing Costs			
Picture Naming	• (*Accuracy*) Named more pictures in Spanish in the pure language condition compared to the mixed language condition. • (*Reaction Time*) Overall picture naming was slower in the mixed language condition.	• (*Accuracy*) No effects observed. • (*Reaction Time*) Overall picture naming was slower in the mixed language condition.	• (*Accuracy*) Named more pictures in English in the pure language condition compared to the mixed language condition. • (*Reaction Time*) Overall picture naming was slower in the mixed language condition.

5.2. Emotion Effects

Contrary to prior work, we did not replicate the effect of negative words on switch costs, nor did we find differences across languages or groups for emotional processing. Looking at how fast participants classified emotion words, there was a main effect of emotional valence. Positive words were classified faster than negative words regardless of group or language. For both heritage groups, emotion words in English were classified faster than the heritage language. Interestingly, there was no language difference for the late bilingual group in Mexico. The work reporting an advantage of L1 on emotional processing is mainly based on the experience of unbalanced late bilinguals (e.g., Jankowiak & Korpal, 2018; Tang et al, 2025). The lack of a language difference may be due to other extraneous task demands in the study. Aside from language switching, participants were also task switching between the emotion word classification and the picture naming trials. Using bootstrapping and structural equation modeling, Yow and Li (2015) used bootstrapping and structural equation modeling to examine which aspects of the bilingual experience predict task switching abilities and found that bilinguals who used both languages frequently and had comparable levels of proficiency in both languages showed reduced mixing cost. Since the bilinguals in Mexico are used to a single-language context and also reported the greatest difference in proficiency across the two languages, the cost of task switching may have obfuscated other cognitive costs such as emotional processing in the L2 or overall language switch costs. In the case of the two heritage groups, the constant demands of their dual-language interactional context may have decreased both task switching and language switching costs.

Although not in relation to switching, an effect of emotional valence and standardized reaction time to the emotion word classification task was observed in the picture naming task. That is, whether the word was positive or negative and how fast they classified the word as such affected following picture naming trials. Given the interest in negative emotions on cognition, we will frame the results centering the effect of negative words on picture naming reaction time. After processing negative words, participants were overall slower to name the following picture.

This slowing of language production by negative words has been documented in previous studies. White et al. (2016) had English native speakers complete a picture naming task were taboo, negative and neutrals distractors were presented alongside the picture. Their results suggest a slowing in picture naming in the presence of taboo words and, to a less degree, negative words. Meanwhile, Hinojosa et al. (2017) recorded electrophysiological data while native Spanish speakers performed a grapheme monitoring task after inducing negative, neutral and positive moods. Behavioral results showed a trend of longer reaction times after negative moods compared to neutral moods and the ERP analysis suggests that negative mood disrupts processes involved in the selection of phonological representations during speech. The findings of the present study provide further evidence about the effect of negative valence content on speech production. Yet to be answered is whether the mechanisms that slower naming are also behind the effect of negative emotions on language switch costs.

The other emotion-related effect observed in this study concerned response times in the emotion-word classification task: the longer participants took to correctly classify an emotion word, the longer they took to name the picture on the subsequent trial. One possibility is that this effect reflects individual or trial-level differences in the efficiency of emotional and semantic processing. Slower emotion word classification may indicate greater difficulty accessing, evaluating, or categorizing the word's emotional content, particularly when emotional processing is less automatized in a less proficient language (Pavlenko, 2012).These processing demands may carry over to subsequent lexical retrieval. Conversely, efficient classification may allow participants to disengage more rapidly from the word and perform better in the picture naming trial. If the effect were driven by a slower access to semantic or emotional content, then we should have seen a differentiated effect for languages; specially in the case of the Mexico group and US Spanish heritage group since they showed consistent language differences.

A second related possibility is related to the transition between the emotion word classification and picture naming tasks. Because each picture-naming trial required participants to disengage from the preceding classification task and engage a different task set (task switching), longer classification times may index greater processing demands or delayed disengagement from emotional/semantic processing (Rogers & Monsell, 1995). This lingering processing could increase the time required to initiate lexical retrieval on the subsequent picture naming trial. Following this logic and our previous description of task switching difficulties in the Mexico group, then we would hypothesize an interaction between reaction time in the emotion word classification task and group. Distinguishing between these two accounts falls outside of the scope of the present design but future studies using similar designs need to account for emotion effects vs task switching effects.

An important distinction in the current finding is the lack of an overall switch effect in the mixed language block. The current design had participants silently read and classify emotion words while Liu et al. (2023) had participants verbally respond. The lack of a switching effect could be due to a switch between modalities: comprehension (emotion word classification) and production (picture naming). For example, Liu et al. (2020) used a comprehension and production language switching task and found task switching effects (going from comprehension to production induces cost) but only language switch costs within modality (i.e., production). However, Li and Gollan (2022) compared Spanish-English bilinguals either switching between naming pictures and reading aloud or semantically classifying written words as either animals or not. They did not find a switch cost in the read aloud condition but did observe a switch cost in the semantic word classification, which is the most similar to the present study. Switch costs between modalities can also be asymmetrical such as the study of Wang et al. (2026) where they found switch costs from L2 comprehension to L1 production but not from L1 comprehension to L2 production. Given that previous studies using cross-modal language-switching paradigms have reliably observed switch costs, the absence of a switch cost in the present study is unlikely to be solely due to our adapted paradigm. Potential explanations could be the unique demands of classifying emotion words, as opposed tasks used in other studies such as lexical decision or animacy classification. Thus, the absence of switch costs may suggest that attending explicitly to emotional information alters the cognitive demands involved in subsequent language switching and/or naming, potentially changing how language processes are recruited.

6. Conclusion

In summary, the present study provides further insights into the role of interactional context and emotional processing in bilingual language control. First, we provide a nuanced characterization of three distinct interactional contexts that are bound not only by geographical location (Mexico vs. US) but also by the variation of bilingual experiences within those locations (US Mandarin vs Spanish heritage speakers). As the field increasingly recognizes the substantial heterogeneity that characterizes bilingual experience, greater attention has been directed toward developing measures that capture this variability rather than relying solely on broad categorical classifications. The present study addresses this concern by incorporating multiple measures of language experience and interactional context. Our battery of questionnaires and language production tasks allowed us to identify varying levels of sensitivity to language control as seen by order effects, mixing costs, and dominance effects. Future research should continue to prioritize such approaches when characterizing bilingual populations.

Our findings should be interpreted considering the limitations of the present study. The sample sizes of the groups are not equal, and the overall study sample size constraints the statistical power of our analyses. Future studies should also consider expanding the number of trials in the mixed language block given that the effect of emotion on language control may be more fine-grained than the present design allows to be observed. Lastly, we had initially conceptualized the reaction time in the emotion word classification task as a proxy for emotional processing. However, simply classifying words as either positive or negative may not provide enough nuance to capture emotional processing. A possible revision to this paradigm may be providing a more emotionally engaging task or employing neurophysiological methods that may capture emotional processing in a more fine-grained matter (e.g., ERPs, skin conductance responses). Still, even when taking those considerations, we did observe an effect of emotional valence which suggests that emotional processing did occur in both languages, contrary to the claims of emotional processing being constrained to the L1. The effect of negative words on overall naming performance was evident in both languages for all groups.

In Study 2, we addressed some of the limitations from the present study with Spanish heritage speakers completing two blocks of our emotion language switching paradigm while electrophysiological data was recorded. Through an analysis of event-related potential, we examined not only the effect of emotion on language switching, but also the processing of emotional words in the emotion word classification task. To preface the findings, electrophysiological data provided insights not seen in behavioral outcomes.

CHAPTER 4: It is Hard to Shake the Negative Feeling: An ERP Study on the Effects of Emotion on Bilingual Language Regulation

Abstract

Initial evidence suggests that negative emotions can influence bilingual language switching, potentially through its effects on inhibitory control. Yet little is known about the time course of these emotion effects during language processing or whether these effects differ across a bilingual's languages. In the present study, Spanish-English heritage bilinguals completed a cued language-switching task interleaved with an emotion-word classification task while electrophysiological activity was recorded. We examined ERP components associated with emotional processing (EPN and LPC) and language switching (N2, N400, and LPC), alongside behavioral performance. Emotional word processing revealed language differences at later stages of processing, with language dominance moderating the effect. In the language switching task, an effect of negative words on switch trials was observed across different stages of language switching and with unique effects for the heritage language, Spanish. Together, these findings demonstrate that the influence of emotion on bilingual language regulation unfolds dynamically over time.

1. Introduction

Emotional information is difficult to ignore. Emotional words can rapidly capture attention and influence ongoing processing, even when their emotional content is irrelevant to the task at hand. For bilingual speakers, emotional processing occurs within a cognitive system that must simultaneously manage the activation and selection of two languages. Thus, emotional processing and bilingual language regulation may place overlapping or competing demands on cognitive resources. Initial evidence suggests that negative stimuli (e.g., words, Liu et al., 2023;

mood, Liu et al., 2026a) can influence language switching by potentially facilitating the transition from one language to another. Yet the relationship between emotion and bilingual language processing may be bidirectional: emotions may influence how bilinguals regulate their languages, but bilingual language experience may shape how emotional information is processed. Using electrophysiological data and event-related potentials, the present study seeks to understand that bidirectional relationship by examining the temporal dynamics of emotional processing and language regulation in Spanish-English heritage bilinguals.

1.1. Bilingualism and Emotions

Many past studies report differences in emotional experiences between a first acquired (L1) and a second acquired language (L2). Dewaele (2004, 2008) analyzed survey data on bilinguals' emotional practices in their L1 and later learned languages and found stronger ratings of emotional weight for both positive (i.e., expressions of "I love you") and negative (i.e., swear and taboo words) words in the L1. In addition, language experiences such as L1 attrition, naturalistic vs formal learning, and frequency of language use modulated the rating for both L1 and later acquired languages. Differences have also been observed for the retelling of autobiographical memories (e.g., Marian & Kaushanskaya, 2008; Noguera et al., 2022) as well as expressions of anxiety (Williams et al., 2026) or guilt (Kyriakou et al., 2024). Cross-linguistic differences arise in how intensely bilinguals express themselves in their languages or their comfort in narrating issues like anxiety or guilt in a nonnative language.

The difference in languages is not limited to the expression of emotions but has also been found in how bilingual speakers process emotional information. Bilinguals seem to process emotional information faster, more automatic and more embodied (e.g., physiological reactions) in their L1 than in their L2 (Pavlenko, 2012). For example, Harris et al. (2003) measured the skin conductance responses of Turkish-English late bilinguals as they rated taboo words and childhood reprimands. They observed stronger physical reactions to the L1. In a later study, Harris (2004) replicated the finding for Spanish-English late bilinguals with heightened sensitivity to L1 reprimands and taboo words. Critically, the same was not found for early English-Spanish bilinguals whose skin conductance responses were similar across both languages.

Another example of L1 vs L2 differences in emotional processing is the research on the foreign language effect on decision making. Studies have reported reduced susceptibility to framing effects and loss aversion (Keysar et al., 2012; Xing, 2021), as well as shifts in responses to moral dilemmas (Geipel et al., 2015; Hayakawa et al., 2017), when bilinguals make decisions in a nonnative language (see Purpuri et al. (2025) for a recent review). The effect of the foreign language on decision making provides insights into the extent to which bilingual emotional processing may affect cognition. Decision making engages multiple cognitive mechanisms such as selective attention, working memory, updating, and value assessment. Emotional information influences these mechanisms by making some information more salient, competing for cognitive resources in working memory and semantic processing, as well as shifting risk assessments of potential outcome.

The modulation of cognitive processing by emotion represents one proposed mechanism underlying the foreign language effect. If the emotional consequences of processing information differ across a bilingual's languages, those differences may extend beyond decision making to other behaviors that depend on overlapping control mechanisms. Furthermore, while the research on bilingual emotional processing favors the L1, other evidence (Harris, 2004; Vargas Fuentes et al., 2022; Thoma, 2024) suggests that language experience (e.g., age of acquisition, language dominance) is a key factor in predicting whether language differences in emotional processing are observed.

1.2. Bilingualism and Language Regulation

The two languages of a bilingual speaker are always active, even when only one of them is being used. Dual-language activation creates a constant need to manage the interference of the nontarget language. The regulation of competing languages has been proposed to depend partly on domain-general cognitive mechanisms. A standard language production paradigm used to examine language regulation is cued-language switching. In this task, participants are instructed to name pictures (e.g., Misra et al., 2012, Mishra & Asthana, 2026) or digits (e.g., Jackson et al., 2001) with a visual or auditory cue indicating the language to be spoken. Trials are constructed to be either in the same language as the preceding trial (e.g., L1 to L1), known as either a stay or language repeat trial, or to be named in a different language to the preceding trial (e.g., L1 to L2), known as a switch trial. The critical finding, first reported by Meuter and Allport (1999) is that switching languages exerts additional demands on the more dominant language, typically the L1, with larger costs to naming latencies.

While switch costs are a result of language regulation demands, not all bilinguals present similar patterns of switch costs. First, switching back to the previously regulated dominant language incurs stronger costs. The strength of downward regulation of the dominant language produces a lag when trying to reengage it because regulating a dominant language is more cognitively effortful than regulating the activation of a weaker language. The relative strength of language regulation for each language results in asymmetrical switch costs (Meuter & Allport, 1999; Costa & Santesteban, 2004; Misra et al., 2012). In the case of balanced bilinguals, those who are relatively dominant in both languages, we would expect to see symmetrical switch costs.

This is exactly what Costa and Santesteban (2004) found with highly proficient Catalan-English bilinguals performing a cued-language switching picture naming task. Switch costs were observed for both L1 Catalan and L2 Spanish, but the magnitude of the costs were equivalent across both languages. Symmetrical switch costs in balanced bilinguals have been replicated in other studies (e.g., Han et al., 2022).

Proficiency is not the only factor that modulates language regulation. Bilingual language regulation is also shaped by individuals' experiences using and managing their languages across different contexts. Some contexts support both languages, allowing for language mixing and codeswitching opportunities to occur. Other contexts are more language restrictive, and languages may be kept separate and used in distinct settings such as home or work. Green and Abutalebi (2013) define these two contexts as either dual-language or single-language interactional contexts and their Adaptive Control Hypothesis framework provides distinct predictions on how these two contexts differentially engage language regulation and domain-general cognition. Empirical evidence testing these predictions comes from studies comparing bilinguals in different interactional contexts, where the environment plays a role in determining how the two languages can be used.

In a 2020 study, Beatty-Martínez et al. compared three groups of Spanish-English bilinguals in Spain, Puerto Rico, and the US. The Spain context can be described as a single-language interactional context where Spanish is used almost exclusively, English is used in limited and predictable settings such as work, and bilinguals rarely codeswitch or mix their languages. Meanwhile, the interactional contexts of Puerto Rico and the US are varied with moments where only one language can be used, and others where there are opportunities to use both Spanish and English. Their findings suggest that bilinguals across these different contexts support their language regulation through different cognitive control styles: proactive and reactive control. However, geographical location is not the only way to examine the role of language experience in language regulation.

In Study 1 of this dissertation, two of the three groups came from the same public university in Southern California. Heritage speakers of Mandarin and of Spanish completed a picture naming task with both pure and mixed language blocks. Examining performance on the picture naming task, different patterns emerged for behavioral markers related to language regulation in spoken production, such as block order effects (i.e., the difference in completing a language first or second) and mixing costs (i.e., the cost of naming in a mixed language context vs a pure one language only). Although both groups were heritage speakers in Southern California, the Spanish heritage group showed asymmetrical language sensitivities to language regulation demands in comparison to their Mandarin counterparts. Spanish heritage speakers showed greater costs when regulating English, the societal language, whereas Mandarin heritage speakers showed largely comparable effects across Mandarin and English. This finding indicates that speakers in the same geographic region may experience different interactional contexts that shape language dominance and regulation.

1.3. The Effect of Emotion on Language Regulation

Studies investigating the effect of emotions on bilingual language regulation are fairly recent. Liu et al. (2023) adapted a cued-language switching picture naming task to include an emotion manipulation. Before each picture naming trial, emotional words were auditorily presented in either the L1 or L2 of Chinese-English bilinguals in China. They were tasked with verbally classifying the word as either positive or negative in the same language of presentation (e.g., they responded in English when they heard an English word). The following picture naming trial was either named in the same language as the emotion word (stay trial) or in a different language (switch trial). Liu et al. found that after processing negative words, there was no difference in reaction times between switch and stay trials whereas, after positive words, there was still a switch cost. The specific effects of emotion on language switching were further disassociated by brain imaging data collected through fMRI. After positive words, there was stronger neural activation after switch trials compared to stay trials, specifically in brain regions associated with cognitive control as well as language and emotional processing. This difference in neural activation was reduced after processing negative words.

In a more recent study, Liu et al. (2026a) examined the effect of emotional states on varying frequencies of language switching while recording electrophysiological data (EEG). Chinese-English bilinguals completed different blocks of picture naming with either 25%, 50% or 75% switch trials after being induced to either neutral, positive or negative states. Throughout the task, participants also completed Flanker test trials which measure conflict resolution and inhibitory control. Event-related potential (ERPs) analyses revealed a reduced N2 component for switch trials during negative states in the medium 50% condition whereas there was no effect of emotional state in the low 25% and high 75% switching blocks. In the high 75 % switching block, Liu et al. observed pronounced P3 amplitudes in the incongruent trials during the positive states, but more pronounced P3 amplitudes in congruent trials during the negative state. In their proposed Emotion Adaptative Control framework, they interpret these results as negative priming facilitating resource allocation to cognitive control in the medium 50% switch condition. In the high switch frequency, they argue that positive states engage proactive control whereas negative states engage reactive control, as evidenced by the P3 effects on the Flanker test.

Wang et al. (2024) reported different effects of positive and negative moods on L1 and L2 switching. Behaviorally, a happy mood facilitated L1 switching, improving both accuracy and reaction time efficiency, whereas a fearful mood facilitated the speed of L2 switching. The ERP results converge with the behavioral findings. Happy mood showed a modulation of L1 switch trials at the P1, N2, and N400 components whereas fearful mood modulated L2 switch trials as evidenced by pronounced N400 and N600 components. The authors interpret these results as mood affecting switching during early attentional allocation (P1 and N2) and semantic processing (N400 and N600). Overall, the findings indicate that emotion can modulate bilingual language switching in a language and time dependent manner, with positive emotion primarily facilitating L1 switching across relatively early through attentional and lexical-semantic stages, and negative emotion facilitating L2 switching during later semantic processing.

Overall, the converging results from these initial studies suggest an effect of emotions in language switching via the engagement of distinct cognitive and language processed. There is a substantial amount of research documenting the intricate relationship between emotions and cognition (see Pessoa (2008) for a review). Emotionally salient information can alter cognitive processes such as attention, inhibition, and conflict resolution. In a study using an emotional Stroop task, Zinchenko et al. (2015) found an effect of negative words on incongruent trials. Negative words seemed to facilitate conflict resolution in incongruent trials in the Stroop task as evidence by faster reaction times when compared to the positive word condition. The relation between emotions, in particular negative emotions, and cognition represents a viable pathway to explain the potential influence of emotions on bilingual language switching.

1.4. Emotional and Language Regulation in Event Related Potentials

A great amount of what we know about language regulation as well as general language and emotional processing in bilingual speakers comes from behavioral experiments. Although behavioral measures provide critical insight into the outcomes of processing and language regulation, they may not always be sensitive enough to capture more subtle differences in bilingual processing (e.g., Bice & Kroll, 2019; Declerck et al., 2021; Morrison & Taler, 2023). In addition, behavior alone cannot reveal when during processing such differences emerge. Event-related potentials (ERPs) offer a temporal view into the unfolding processes that preceded an observable response, like language production. By looking at ERPs during emotional processing and language regulation, we are able to examine the temporal dynamics and the underlying cognitive mechanisms that support these processes in bilingual speakers. In particular, we can distinguish whether effects emerge during early attentional or control processes, lexical semantic processing or during later evaluative or monitoring stages. In the following section, we briefly review a targeted set of ERP studies examining emotional processing and language regulation in bilingual speakers.

1.4.1. Emotional Processing

Studies investigating emotional processing in bilinguals have examined differences between emotional and neutral words in the Early Posterior Negativity (EPN) and the Late Positive Component (LPC) components. The EPN is characterized by a negative going amplitude during early stages of processing (around 100-300ms after stimulus onset) and it is associated with engaging attentional resources. For emotional processing, EPN amplitudes are more pronounced after processing emotional word (but see Shupp et al. (2003) for pictures) compared to neutral content. Meanwhile, the LPC is a later stage of processing (around 500 ms after stimulus onset) characterized by a positive going amplitude. The LPC has been related with higher level semantic evaluation and shows sensitivity to differences between emotional and neutral words (Citron et al., 2013) as well as between positive and negative words (Zhang et al., 2014).

Studies investigating bilingual emotional processing have reported differences between the L1 and L2 in the EPN and LPC (Chen et al., 2015; Tang et al., 2025). Tang et al. (2025) examined two types of emotion words in late Chinese-English bilinguals: emotion-laden, words with emotional connotation (e.g., death), and emotion-label, words that denote emotional states (e.g., happy). For both languages, they found that negative words elicited more pronounced EPN amplitudes relative to positive words, and emotion-laden words produced pronounced EPN amplitudes relative to emotion-label words. Language differences emerged during later processing, with emotion words eliciting attenuated LPC amplitudes in the L1 relative to the L2. More specifically, Additionally, the overall LPC amplitude was more positive for L2 emotion words than for L1 emotion words, especially in the case of positive words.

Other studies have found comparable electrophysiological activity for the L1 and L2 (e.g., Vélez-Uribe & Rosselli, 2021; Conrad et al., 2011) for balanced bilinguals. For example, Conrad et al. (2011) compared two groups of highly proficient bilinguals in an emotional lexical decision task while collecting EEG data. Contrary to prior claims of superior L1 emotional processing, results showed comparable sensitivity to L1 and L2 emotion words indicated by EPN and LPC components in the ERP analysis. The EPN and LPC amplitudes were more pronounced for both negative and positive words compared to neutral words across the two languages, although latencies of the ERP components differed temporally by 50-100ms.

1.4.2. Language Regulation

ERP studies examining bilingual language regulation in language switching paradigms have looked at differences between switch and stay trials in the N2, N400 and LPC. The N2 is a negative going amplitude after 200 ms after stimulus onset. It is related to early engagement of inhibitory control when a response needs to be inhibited or suppressed (Wang et al., 2024). In the case of language regulation, switch trials elicit more negative N2 amplitudes than stay trials (Jackson et al., 2001; Verhoef et al., 2009; Zheng et al., 2020, but see Wodniecka et al. (2020) for evidence supporting an N300 component instead). Martin et al. (2013) found differences in the N2 amplitude of early and late bilinguals switching between their stronger L1 and weaker L3. The differences were explained by the difference in regulating a stronger vs weaker lexical activation and re-engaging it in the switch trial.

The N400 component is characterized by a prominent negative wave around 300-500 ms post stimulus presentation. Generally, the N400 is related to lexical and semantic processing with more negative N400 amplitudes when processing semantic inconsistencies (Lau et al., 2008) or, in the case of language switching, when there is difficulty retrieving lexical items. Kang et al. (2020) found that switch trials were associated with slower picture naming responses and elicited larger N2 and N400-like components than stay trials. The authors interpreted the N400 switch effect as reflecting increased demands on lexical processing during bilingual language control, suggesting that the consequences of switching extend beyond earlier control-related processes into later stages of word production.

At later stages of bilingual language production, switch effects have also been observed in the LPC, typically emerging approximately 400–650 ms following stimulus onset. These later effects have been associated with processes involved in lexical selection, response selection, and the reconfiguration or monitoring required to produce a response in the intended language. For example, Jackson et al. (2001) examined the neural correlated involved when late language learners named digits in either their L1 English or their second language. They found increased negativity of the N2 component, especially when switching from L1 into L2. They also observed a larger positivity in the LPC component for switch trials relative to stay trials. These findings, as well as the other studies reviewed in this section, suggest that language switching recruits processes extending across multiple stages of production, from relatively early control processes reflected in the N2, through lexical-semantic processing reflected in the N400, to later response-selection, reconfiguration, and monitoring processes reflected in the LPC.

1.5. The Present Study

The present study examined cross-linguistic differences in emotional processing in heritage bilinguals as well as the effect of emotion on bilingual language regulation. Spanish heritage bilinguals completed a cued-language switching picture naming task interleaved with an emotional word classification task while their electrophysiological activity was recorded using EEG. One study goal was to determine whether the documented effects of negative content on language switching could be replicated (e.g., Liu et al., 2023; Liu et al., 2026a; Liu et al., 2026b). Another goal was to test the constraints of emotional processing across first and second acquired languages by exploiting the experience of heritage bilinguals. Given their lifelong immersion in an English environment, most heritage speakers in the US experience a dominance shift where English becomes their dominant language. Experience with the heritage language, on the other hand, is more varied since heritage speakers vary in terms of heritage language use, proficiency, educational opportunities, etc. We predicted that Spanish heritage speakers may show neurophysiological sensitivities to emotional processing in each language, but such sensitivity will be modulated by their language experiences (e.g., language dominance).

2. Participants

A total of 49 Spanish heritage speakers participated in this study. They all reported acquiring Spanish (*M* = 0.33, *SD* = 1.22) and English (*M* = 4.12, *SD* = 2.77) early in life. Overall, participants self-rated themselves higher in English than Spanish across all aspects of language abilities (i.e., reading, writing, speaking, and understanding). The average language dominance score, as calculated by the Bilingual Language Profile (BLP; Birdsong et al., 2012) questionnaire, was 25.48 with a *SD* of 32.42 and within a range of [-59.93 - 74.47]. There was a wide spread of language dominance with some speakers being more Spanish dominant (lower scores), others with more balanced dominance (scores closer to 0) and the majority being English dominant (higher scores).

Table 3. Participant Descriptive Statistics

	Mean (SD)
Sample Size	49
Age (yrs.)	20.78 (3.48)
Females (N)	36
English	
Age of Acquisition (yrs.)	4.12 (2.77)
Overall Self-rated Proficiency	22.61 (2.08)
Speak	5.57 (0.61)
Understand	5.80 (0.57)
Read	5.71 (0.53)
Write	5.53 (0.73)
Spanish	
Age of Acquisition (yrs.)	0.33 (1.22)
Overall Self-rated Proficiency	19.04 (3.02)
Speak	4.57 (0.99)

Understand	5.31 (0.84)
Read	4.96 (0.95)
Write	4.20 (1.03)

Note: For the measures of age of acquisition and self-rated proficiency, the value shown is mean (standard deviation). The possible range for Overall Proficiency is [0,24] and for each subcomponent (e.g., Read, Write) the range is [0,6]. Self-rated proficiency was gathered through the Bilingual Language Profile Questionnaire.

3. Methods

3.1. Verbal Fluency Task

We administered a semantic verbal fluency task as a measure of both language proficiency and dominance. Participants were presented with semantic categories (e.g., fruits) in either English or Spanish and were asked to name as many unique exemplars as possible in the target language in thirty seconds. They completed two language separate blocks with 4 semantic categories each. The presentation of the categories and the order of the language blocks was counterbalanced across participants. Oral responses were recorded, transcribed, coded and quality checked by undergraduate research assistants proficient in both Spanish and English.

3.2. Picture Naming Task – EEG Session

The picture naming task used while recording EEG data was an adaptation from the Liu et al. (2023) paradigm and slightly different than the one used in Study 1. Participants completed two mixed language blocks, each with 80 picture naming trials. Before each trial, participants were shown an emotion word on the screen in either English or Spanish. They were asked to classify the emotion word as either positive or negative via button press. After classifying the word, a picture was presented within a color frame which served as a cue for the target language (e.g., blue frame for English, red frame for Spanish). Participants were instructed to press a button when they began to name the picture; a similar method of collecting naming latencies has been used for bimodal bilingual studies such as Declerck et al. (2021). Button press, as opposed to onset time in Study 1, served as a measure of naming latencies (reaction time). Oral responses were recorded through an external recording device, and the audio was transcribed and coded for accuracy by undergraduate research assistants proficient in Spanish and English. We used the same scoring parameters as in Study 1 and completed an extra round of quality checking to ensure similar coding was applied to both studies' datasets.

3.3. Procedure

All tasks were presented using E-Prime (v. 3.0) on a desktop computer. Responses were recorded via a Chronos response button box with a millisecond-accurate reaction time tracking feature. Oral responses to the verbal fluency and picture naming task were recorded using an external recording device. Participants were part of a larger project on bilingual variation and its effects on language processing. As such, they completed numerous tasks which are not all detailed in the present study. For the tasks discussed in this publication, all participants completed the Bilingual Language Profile questionnaire at home via google forms. They then completed an in-person behavioral session where they completed a series of cognitive and language tasks, including the verbal fluency task and a picture naming task without the emotion words. The same pictures used in that picture naming task in the first session where then use in the subsequent EEG session. The time between the first behavioral session and the second EEG session was approximately a week for most participants. While in the EEG session, all participants completed two language tasks, one of them the picture naming task detailed in this study.

3.4. Electrophysiological Data

Electrophysiological data was collected using 32 Ag/AgCI scalp electrodes placed in accordance with the 10-20 system and recorded on Brain Vision Recorder (v.2.3). All data was preprocessed offline using Brain Vision Analyzer (v.2.3). Electrodes were re-referenced to the average of the left and right mastoids and filtered. Continuous EEG data were then filtered using a four-order infinite impulse response (IIR) with a low cutoff of 0.1 Hz and high cutoff of 30 Hz. Following re-referring and filtering, the continuous data were visually inspected to identify periods with abnormal or nonphysiological activity. Training trials, experimental breaks, and periods of signal drift were excluded during this inspection. Ocular artifacts, such as blinks and saccades, were subsequently identified and corrected using a semiautomatic independent component analysis (ICA) with classic sphering, PCA, and Infomax.

Average event-related potentials (ERP) were calculated for each condition in the emotion word classification task, Emotion (Positive vs Negative) x Language (English x Spanish), and for each condition in the picture naming task, Emotion (Positive vs Negative) x Target Language (English vs Spanish) x Switch (Stay trial vs Switch trial). Stimulus onset was locked to either the emotion word presentation or the picture presentation with a time baseline 200ms before stimulus onset and a total epoch duration of 1000ms. Based on previous studies, regions of interest and time windows for each component were selected a priori and verified by examining scalp distributions and average ERP waveforms. To examine the processing of positive and negative words in the emotion word classification task, analyzed for two components: the Early Posterior Negativity (EPN) around 100-300 ms and the Late Positive Component (LPC) around 400-600 ms post stimulus onset. Using a moving window of 100ms, the amplitude was average across parietal (P3, P4), parieto-temporal (P7, P8) and occipital (Oz, O2) regions for the EPN component; and for five centro-parietal electrodes (CP1, CP2, P3, Pz, and P4) for the LPC. To examine the effect of emotion words in the picture naming task, three ERP components were studied in the following time windows: N2 (100-300 ms), N400 (300-500 ms), and an LPC (500-

700 ms). Only correct trials were included for the analysis on the emotion word classification task.

All analyses were conducted in R Studio (R version 4.6.1; R Core Team, 2026). The average amplitude (μV) of each component's ROI was fitted using a linear-mixed effect model using the lme4 (Douglas Bates et al, 2015) and lmerTest (Kuznetsova et al. 2017) R package. Participants were included as random intercepts and by-participant random slopes for Language, Emotion, Time Window, and, when necessary, Switch. Random-effect correlations were constrained to zero to reduce model complexity and facilitate convergence. Contrast coded numeric versions of the experimental factors were used to specify the random slopes with the following reference levels: Language (English), Time Window (the first 100ms interval), Switch condition (Stay trials), and Emotion (Positive). To examine main effects, type III omnibus tests of fixed effects were conducted using the Kenward–Roger approximation for degrees of freedom using the 'car' R package (Fox & Weisberg, 2019). Post-hoc analysis of estimated marginal means and pairwise comparisons were done using 'emmeans' R package (Lenth, 2026).

4. Results

4.1. Behavioral

4.1.1. Verbal Fluency

Linear-mixed effect model analysis yielded a significant language difference and an interaction between language and language order. Overall, participants produced more words in English (*M* = 39.786, *SD* = 1.44) than Spanish (*M* = 26.77, *SD* = 1.55). However, they named more words in English when English was produced first (*EMM* = 39.8, *SE* = 1.44) than when English was produced following Spanish (*EMM* = 34.9, *SE* = 1.71; $\Delta M = 4.89$, *SE* = 2.23, $t(76.5) = 2.19$, $p = 0.03$). The same order effect was not observed for Spanish scores ($\Delta M =$ -

2.18, *SE* = 2.25, *t*(77.1) = -0.97, *p* = 0.34). Observed patterns of higher overall performance and block order effects in English aligns with the findings of Study 1 where English was the dominant language for Spanish heritage speakers.

4.1.2. Emotion Word Classification Task

Mean performance in the emotion word classification time was relatively high for accuracy: English negative words (*M* = 98.2%, *SD* = 13.5), English positive words (*M* = 97.5%, *SD* = 15.6), Spanish negative words (*M* = 97.6%, *SD* = 15.3), and Spanish positive words (*M* = 92.7%, *SD* = 26.0). Accuracy data in the emotion word classification task was fitted to a generalized linear mixed effect model with Language, Emotion and Language Dominance as fixed effect with by-participants random slopes for Emotion and Language. Language dominance was rescaled to allow model convergence. An ANOVA omnibus test of the model showed a significant min effect of Emotion (X^2 = 6.50, *p* = 0.01) and a three-way interaction between Language, Emotion and Language Dominance (X^2 = 6.73, *p* = 0.01).

Follow-up trend analyses indicated that the relationship between language dominance and accuracy differed significantly between positive and negative Spanish words (*estimate* = −0.17, *SE* = 0.07, *z* = −2.34, *p* = 0.02, 95% CI [−0.32, −0.03]), but not between positive and negative English words (*estimate* = 0.08, *SE* = 0.09, *z* = 0.91, *p* = 0.36). For Spanish, increasing English dominance was associated with decreasing accuracy for positive words (*estimate* = −0.20, *SE* = 0.06, 95% CI [−0.32, −0.08]), whereas accuracy for negative words remained relatively stable (*estimate* = −0.03, *SE* = 0.07, 95% CI [−0.16, 0.11]). To better understand the interaction, follow up contrasts analysis were computed across four representative language dominance values: -30, 0, +30, +60. The results of these analyses showed no difference between positive and negative words among relatively Spanish-dominant participants (−30; *odds ratio* = 0.78, *SE* = 0.39, *p* =

0.62), whereas negative words were identified more accurately than positive words at balanced dominance (0: *odds ratio* = 0.46, *SE* = 0.15, z = -2.41, p = 0.02) and at higher levels of English dominance (+30: *odds ratio* = 0.28, *SE* = 0.06, z = -5.52, $p < .001$; +60: *odds ratio* = 0.16, *SE* = 0.05, z = -5.54, $p < 0.001$). No significant valence differences were observed for English words across the examined language dominance values.

For reaction time data in the emotion word classification task, only correctly classified trials were used. Trials with reaction times exceeding or falling below 2.5 standard deviations from the mean were excluded from this and all subsequent analyses. Around 6.04% of data was excluded following these parameters. Reaction time data was fitted using a linear mixed effect model with the same fixed and random structures as the accuracy model. Type III ANOVA omnibus test yielded a significant main effect of Language ($F(1, 57) = 4.35$, $p = 0.04$) and a significant interaction between Language and Language Dominance ($F(1, 56.7) = 5.01$, $p = 0.03$). Since the effect of language is nested within the interaction, we focus our follow up analysis and interpretations on the interaction.

Follow-up comparisons of estimated means at representative language dominance values indicated no difference between English and Spanish naming latencies among relatively Spanish-dominant participants (−30; ΔEM = 2.14 ms, *SE* = 18.10, $p = 0.91$) or at balanced dominance (0; ΔEM = −19.56 ms, *SE* = 11.60, $p = 0.10$). In contrast, English words were classified significantly faster than Spanish words at higher levels of English dominance. At +30 dominance, responses were faster for English than Spanish words (ΔEM = −41.25 ms, *SE* = 9.12, 95% CI [−59.5, −23.0], $p < 0.001$). At the highest English-dominant value (+60), this language difference was even greater (ΔEM = −62.95 ms, *SE* = 13.30, 95% CI [−89.5, −36.4], $p < 0.001$).

In summary, language dominance modulated the effect of emotional valence and language in the emotion picture naming task. Higher English dominance was associated with less accuracy for Spanish positive words. While this interaction is statistically significant, it is important to note that accuracy was close to ceiling effects with overall average performance above 90%. Second, greater English language dominance was associated with faster reaction times for English words overall, aligning with research indicating that stronger emotional effects in the societal language of heritage speakers are often linked to higher language dominance in the language (Vargas Fuentes et al., 2022).

4.1.3. Picture Naming

For the picture naming data, only picture naming trials that were preceded by correctly classified emotion word trials were analyzed. Picture naming accuracy data was fitted to a generalized linear mixed effect model with Language, Switching and Emotion as fixed effects and participants as random intercepts. We also controlled for standardized reaction time in the word classification task given its significant effect on naming latencies in Study 1. The initial random effects structure also included by-participant random slopes for Language, Emotion, and Switch status. However, this model produced an issue of singular fit because the variance of the Emotion random slope was estimated as zero. The Emotion random slope was therefore removed, resulting in a nonsingular final model with by-participant random slopes for Language and Switch status.

A type III Wald chi-square test revealed a main effect of Language ($X^2(1) = 142.17, p < 0.001$) , but no main effect of Emotion ($X^2(1) = 0.76, p$ = 0.38), Switching ($X^2(1) = 1.01, p = 0.31$), nor an effect of standardized reaction time in the emotion word classification task ($X^2(1) = 0.88, p = 0.35$). More importantly, there were no significant two-way or three-way interactions between Language, Switching and Emotion. Follow-up contrasts of the language effect showed a higher odds ratio for English picture naming (Δ *odds ratio* = 5.33, *SE* = 0.75, *z* = 11.94, 95% CI [4.05, 7.02], $p < 0.001$). Better performance in English picture naming aligns with the findings in the verbal fluency scores.

Only the reaction time data of picture naming trials with that were correctly named were considered for the final analysis. Furthermore, trials identified as false reaction times (e.g., naming a picture twice) were also excluded. In Study 1, we identified and excluded absolute outliers with a low cutoff of 300 ms and a higher cutoff of 3000 ms. In the present study, reaction time is recorded through button press instead of voice onset time. Therefore, we identified relative outliers to each participant's mean reaction time and excluded any trials above or below 2.5 standard deviations from the mean. Following this procedure around 23% of the trials were excluded from the analysis.

Reaction time data in the picture naming task was fitted using a linear mixed effect model with Language, Emotion, Switch and standardized time in the emotion word trial as fixed effect. Initial random structures included by-participant random slopes for Language, Emotion and Switch. However, due to an issue of singular fit, the model was restructured to include only by-participant random slopes for Language after checking covariance in the model. The omnibus Type III ANOVA omnibus analysis showed no significant effects or interactions with our predictor variables.

In summary, behavioral outcomes in the picture naming task do not indicate an effect of emotion on language switching nor a modulation of this effect given language or language dominant was significant. We proceed to consider the findings from the electrophysiological data.

4.2. Event Related Potential (ERP)

4.2.1. Early Posterior Negativity (EPN) – Emotional Processing

Analysis of ERP amplitudes related to the EPN time windows (100-200 ms and 200-300 ms) showed no significant effect of Language ($F(1, 45) = 0.17$, $p = 0.69$), Emotion ($F(1, 45) = 0.85$, $p = 0.36$) or an interaction between them ($F(1, 180)= 0.15$, $p = 0.70$). There was a significant effect of Time Window ($F(1, 45) = 68.38$, $p < 0.001$). Estimated means for the time windows suggest more negative amplitudes in the earlier time window (100-200ms, $EMM = -0.14\ \mu V$, $SE = 0.31$, 95% CI [-0.78, 0.48]) compared to the later window of 200-300ms ($EMM = 1.90\ \mu V$, $SE = 0.31$, 95% CI [1.272, 2.52]). The estimated difference between these windows is statistically significant ($\Delta M = -2.04$, $SE = 0.25$, $t(45) = -8.27$, 95% CI [-2.54, -1.54], $p < 0.001$).

A secondary analysis with language dominance as a fixed effect interacting with Language and Emotion was conducted. The language dominance model did not show significant effects of Language ($F(1, 43) = 0.01$, $p = 0.93$), Emotion ($F(1, 43) = 0.89$, $p = 0.35$), Language Dominance ($F(1,43) = 0.07$, $p = 0.79$), nor a three-way interaction between these fixed effects ($F(1, 178) = 2.98$, $p = 0.07$). The main effect of Time Window persisted in this new analysis ($F(1, 44) = 64.88$, $p < 0.001$). Overall, the analyses provided no evidence for an effect of Emotion, Language or Language Dominance on this ERP component.

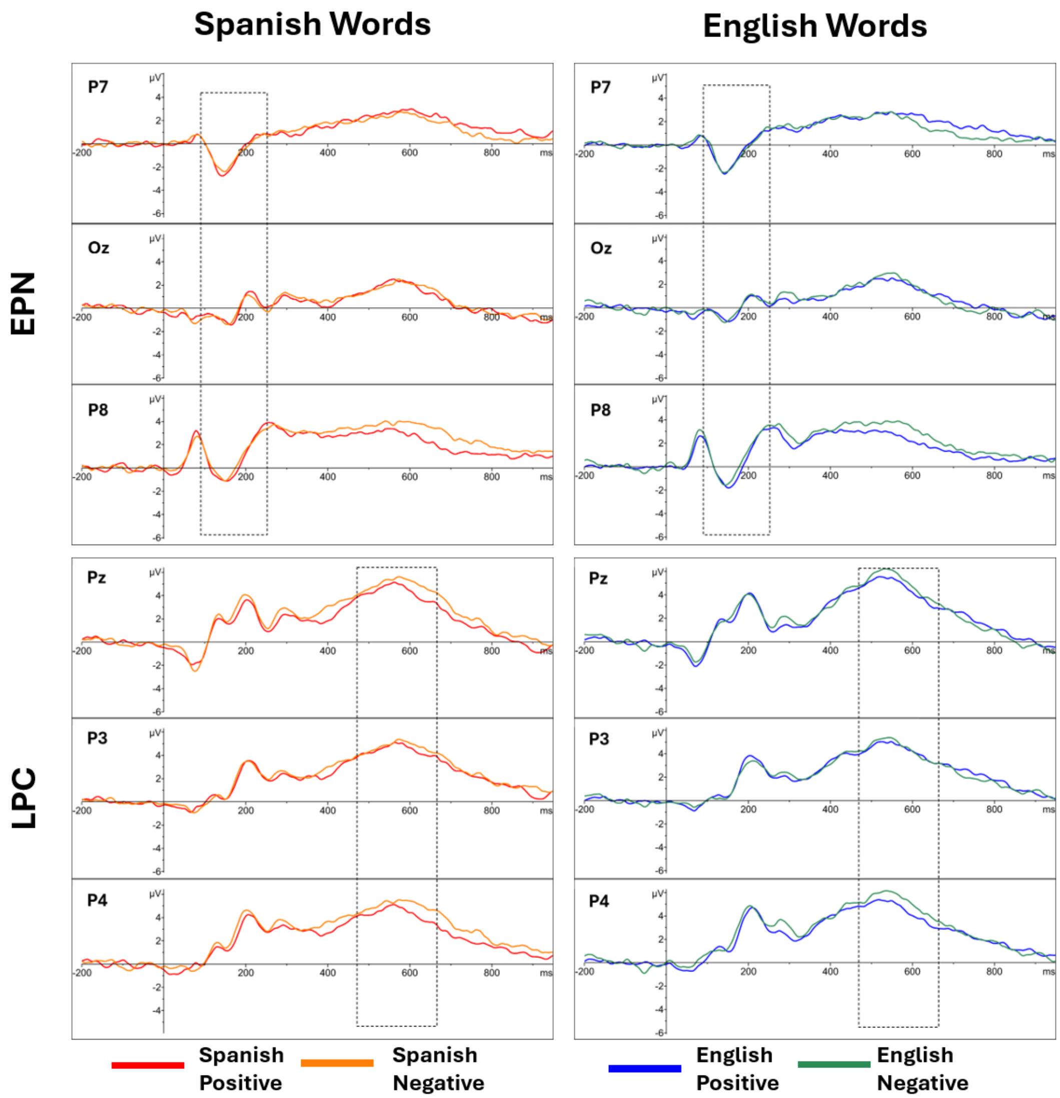


Figure 8. ERP Waveforms for EPN and LPC Components by Language and Emotion

4.2.2. LPC – Emotional Processing

The primary analysis of the LPC component with Language and Emotion as fixed effects and as interactions revealed no significant effect of Language ($F(1, 45) = 2.31$, $p = 0.14$), Emotion ($F(1, 45) = 2.26$, $p = 0.14$), nor a significant two-way interaction ($F(1, 180) = 10.49$, $p = 0.48$). A main effect of Time Window was observed ($F(1, 45) = 20.00$, $p < 0.001$) with more positive amplitudes in the 500-600 ms window (*EMM* = 4.84, *SE* = 0.50, 95% CI [3.84, 5.84]) compared to the earlier window of 400-500 ms (*EEM* = 3.67, *SE* = 0.50, 95% CI [2.66, 4.67]). The contrast between these two windows is statistically significant (ΔM = -1.18, *SE* = 0.26, $t(45) = -4.47$, 95% CI [-1.70, -0.65], $p < 0.001$).

A secondary analysis was conducted with Language Dominance as a fixed effect and moderator of the Language and Emotion interaction. A type III omnibus tests of fixed effects revealed a significant three-way interaction between Language, Emotion and Language dominance on LPC amplitudes, $F(1, 178) = 14.70$, $p < 0.001$. Follow-up trend analyses and pairwise comparisons indicated an effect of language dominance on Spanish positive and negative words ($b = 0.03$, *SE* = 0.01, $t(68.1) = 2.80$, $p = 0.007$, 95% CI [0.008, 0.045]) but not significant in English, $b = -0.01$, *SE* = 0.01, $t(68.1) = -0.73$, $p = 0.47$, 95% CI [−0.026, 0.012]. To understand the effect of dominance on Spanish negative and positive words, we probed the interaction between Language and Emotion at different values of Language Dominance (-30, 0, +30, +60). These values range across Spanish and English dominance while also reflecting the skewed distribution of the data; more English-dominant participants than Spanish-dominant or balanced.

Looking at these representative language dominance values showed that negative words elicited greater LPC amplitudes than positive words for more Spanish-dominant participants (Dominance = −30; $\Delta M = -1.84$ μV, *SE* = 0.60, $p = 0.003$). This difference between LPC amplitudes of negative and positive words in Spanish is also present for more balanced bilinguals (Dominance = 0; $\Delta M = -1.05$ μV, *SE* = 0.39, $p = 0.009$) although the difference is less. When observing higher English dominant values (+30, +60), the emotion effect on LPC amplitudes is no longer significant (+30, ΔM = -0.25 μV, *SE* = 0.32, $p = 0.43$; +60, ΔM = 0.54 μV, *SE* = 0.46,

$p = 0.24$). These findings suggest that the emotion modulation of LPC amplitudes in Spanish was relative to language dominance. The more Spanish dominant, the more positive going LPC amplitudes negative Spanish words elicited to their positive counterparts (See **Error! Reference source not found.**). Meanwhile, an effect of emotion words was not found for English regardless of dominance.

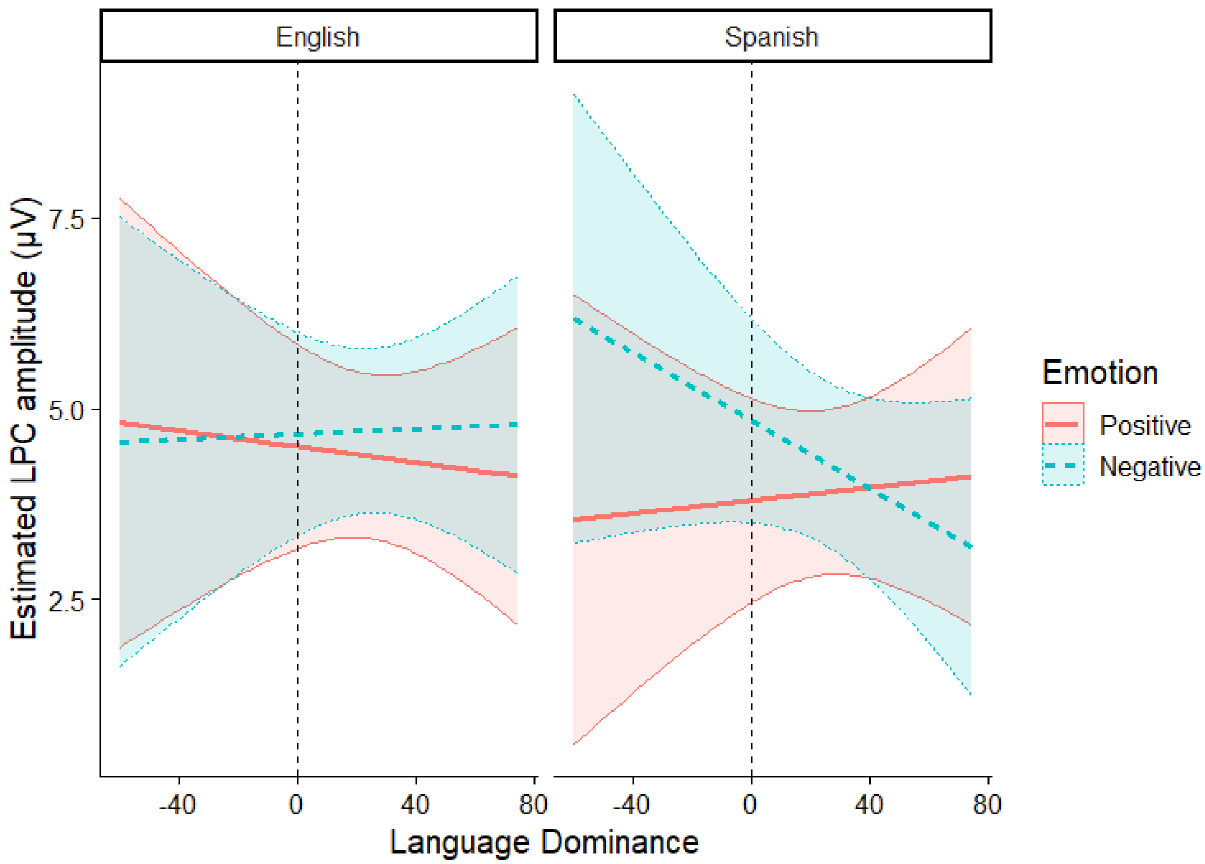


Figure 9. Estimated LPC Amplitude Means by Emotion and Language Dominance

4.2.3. N2 – Picture Naming Task

A primary analysis of Language, Switch, and Emotion as fixed effects and high-order interactions was conducted over two time windows (100-200 ms and 200-400ms) with Time Window as a factor as well. Type III analysis of variance with Kenward-Roger's method showed a significant effect of Language ($F(1, 45) = 11.15$, $p = 0.002$), Time Window ($F(1, 45) = 10.94$,

$p = 0.002$), and a significant interaction between Switch x Emotion ($F(1, 495) = 6.92$, $p = 0.009$). Follow up analysis on the main effect of Language revealed more negative N2 amplitudes for English ($EMM = -0.68\ \mu V$, $SE = 0.58$, 95% CI [-1.85, 0.49]) than for Spanish picture naming trials ($EMM = -0.08\ \mu V$, $SE = 0.58$, 95% CI [-1.25, 1.10]). The contrast between these two mean amplitudes was statistically significant (ΔM English – Spanish = -0.61 µV, $SE = 0.18$, 95 % CI [-0.97, -0.24], $p = 0.002$).

When probing at the significant Switch x Emotion interaction, follow-up contrasts indicated that Switch trials elicited significantly more negative N2 amplitudes than Stay trials following positive words (ΔM Stay − Switch = 0.52 µV, $SE = 0.22$, 95% CI [0.08, 0.96], $p = 0.021$), whereas no significant switch effect was observed following negative words (ΔM Stay − Switch = −0.17 µV, $SE = 0.22$, *95% CI* [−0.61, 0.27], $p = 0.45$). The magnitude of the switch effect differed significantly between positive and negative conditions ($\Delta M = 0.69$ µV, $SE = 0.26$, *95% CI* [0.17, 1.20], $p = 0.01$). The typical switch cost in relation to more pronounced N2 amplitudes was only found after participants processed positive words but not negative words. Critically this emotion effect on switch trials was independent of language ($F(1, 495) = 0.43$, $p = 0.51$). A secondary analysis adding language dominance as a moderator did not show any significant effect or interaction with language dominance ($F(1, 43) = 0.70$, $p = 0.41$).

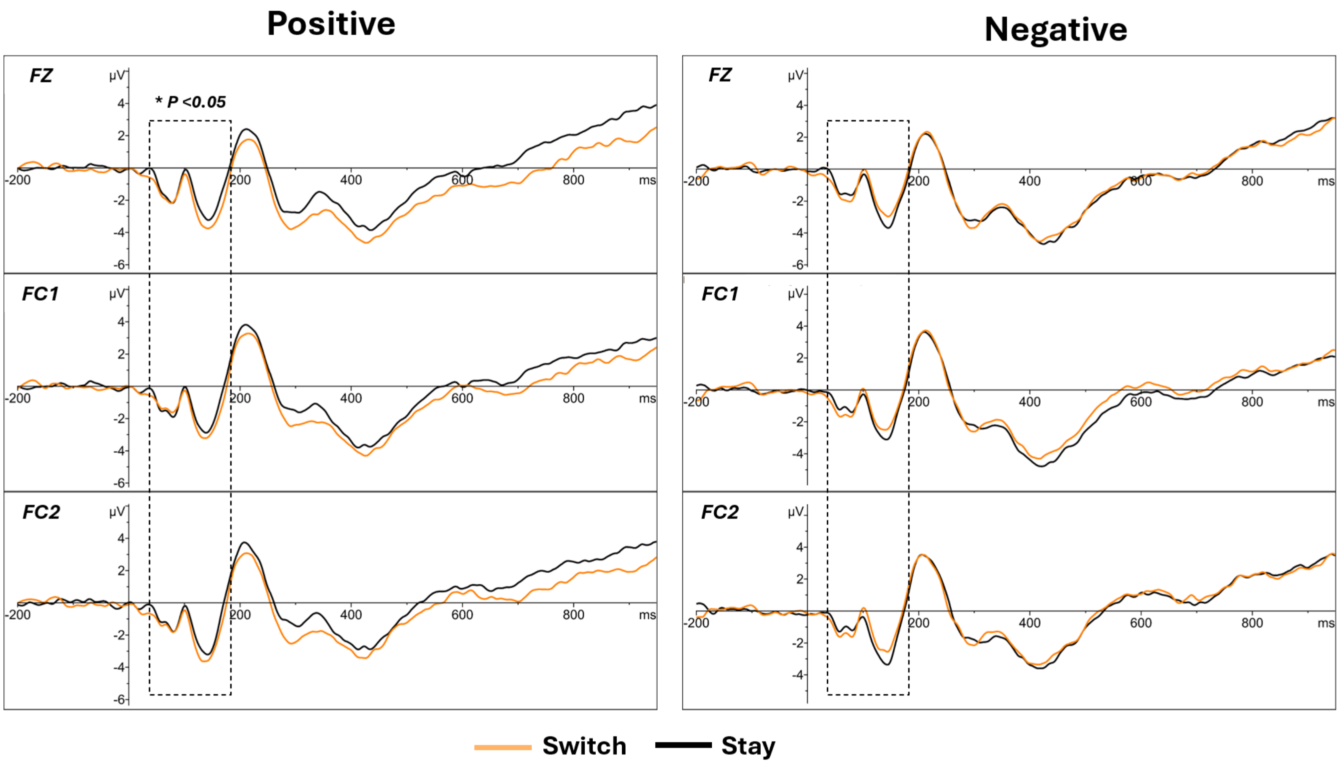


Figure 10. ERP Waveforms for the N2 Component by Emotion and Switching

4.2.4. N400 – Picture Naming Task

A linear mixed-effects analysis examining N400 amplitudes across the 300–400 and 400–500 ms time windows revealed significant main effects of Language ($F(1, 45) = 4.67$, $p = 0.04$, and Emotion ($F(1, 45) = 4.61$, $p = 0.04$), as well as significant two-way interactions between Language x Switch ($F(1, 495) = 4.62$, $p = 0.03$), and Switch x Emotion ($F(1, 495) = 4.56$, $p = 0.03$). These lower-order effects were qualified by the significant Language × Switch × Emotion interaction, $F(1, 495) = 11.72$, $p < .001$. There was no main effect of Time Window, $F(1, 45) = 0.06$, $p = 0.81$.

Follow-up pairwise comparisons indicated that the Switch x Emotion interaction was significant in Spanish picture naming ($b = 1.37$ μV, $SE = 0.35$, 95% CI [0.69, 2.06], $p < 0.001$)

but not in English picture naming ($b = -0.32$ μV, $SE = 0.35$, 95% CI [−1.00, 0.37], $p = 0.36$). Contrary to the N2 findings, Spanish switch and stay trials did not significantly differ following positive words (ΔM Stay − Switch = 0.52 μV, $SE = 0.34$, $p = 0.13$). However, following negative words, switching to Spanish elicited significantly more positive amplitudes than Stay trials (ΔM Stay − Switch = −0.85 μV, $SE = 0.34$, 95% CI [−1.53, −0.17], $p = 0.01$). Neither positive (ΔM Stay − Switch = 0.21 μV, $p = 0.55$) nor negative (ΔM Stay − Switch = 0.52 μV, $p = 0.13$) conditions produced significant switch effects in English picture naming. A secondary analysis with language dominance revealed no modulation of language dominance ($F(1,43) = 0.54$, $p = 0.47$) and the three-way interaction was still significant.

In summary, looking at N400 amplitudes, we observed an effect of emotion on switch trials but only for pictures named in Spanish. After processing a negative word, switching to Spanish elicited more positive amplitudes around the N400 time windows. There was no difference between emotion conditions or switch conditions when naming in English.

4.2.5. LPC – Picture Naming Task

Mean LPC amplitude was analyzed across two time windows: 500–600 and 600–700 ms. The omnibus test analysis revealed a significant effect of Time Window ($F(1, 45) = 8.30$, $p = 0.01$) and a significant three-way interaction between Language, Switch, and Emotion ($F(1, 495) = 5.61$, $p = 0.02$). Similarly to the N400 analysis, follow-up contrasts analysis showed an interaction between switch and emotion for Spanish picture naming ($b = 1.26$ μV, $SE = 0.44$, 95% CI [0.40, 2.12], $p = 0.004$, but not in English picture naming ($b = -0.20$ μV, $SE = 0.44$, 95% CI [−1.06, 0.66], $p = 0.65$). Following negative words, Spanish Switch trials elicited significantly more positive LPC amplitudes ($EMM = 5.35$, $SE = 0.57$, 95% CI [4.23, 6.48]) than Spanish Switch trials ($EMM = 4.55$, $SE = 0.57$, 95% CI [3.42, 5.68]). The contrasts between Switch and

Stay trials in the negative condition was statistically significant for Spanish (ΔM Stay − Switch = −0.80 μV, *SE* = 0.36, 95% CI [−1.51, −0.10], $p = 0.03$). Neither positive nor negative conditions produced significant Switch–Stay differences in English (positive: ΔM Stay − Switch = 0.25 μV, *SE* = 0.36, $p = 0.49$; negative: ΔM Stay − Switch = 0.45 μV, *SE* = 0.36, $p = 0.21$).

There was also a significant main effect of Time Window, $F(1, 45) = 8.30$, $p = 0.006$. Pairwise comparisons showed that LPC amplitudes were more positive during the 500–600 ms window (*EMM* = 5.09 μV, *SE* = 0.51) than during the 600–700 ms window (*EMM* = 4.48 μV, *SE* = 0.51), and the difference was statistically significant (ΔM = 0.62 μV, *SE* = 0.21, 95% CI [0.19, 1.05], $p = 0.006$). The model analysis did not report a significant interaction between Language, Switch, Emotion, and Time Window interaction ($F(1, 495) = 0.02$, $p = 0.89$) which indicates that the Language, Switch, and Emotion pattern did not differ between the 500–600 and 600–700 ms intervals. Finally, a secondary analysis with Language dominance as an interactive fixed effect did not yield a significant main effect ($F(1, 43) = 1.47$, $p = 0.23$) or modulation of language dominance ($F(1, 532) = 0.17$, $p = 0.68$) on the Language, Switch, and Emotion interaction.

In summary, LPC amplitudes showed an effect of negative words on subsequent Spanish picture naming, specifically to switch trials. Following negative words, switching to Spanish elicited more positive LPC amplitudes relative to stay trials. This effect of emotion words on switching was not observed for English.

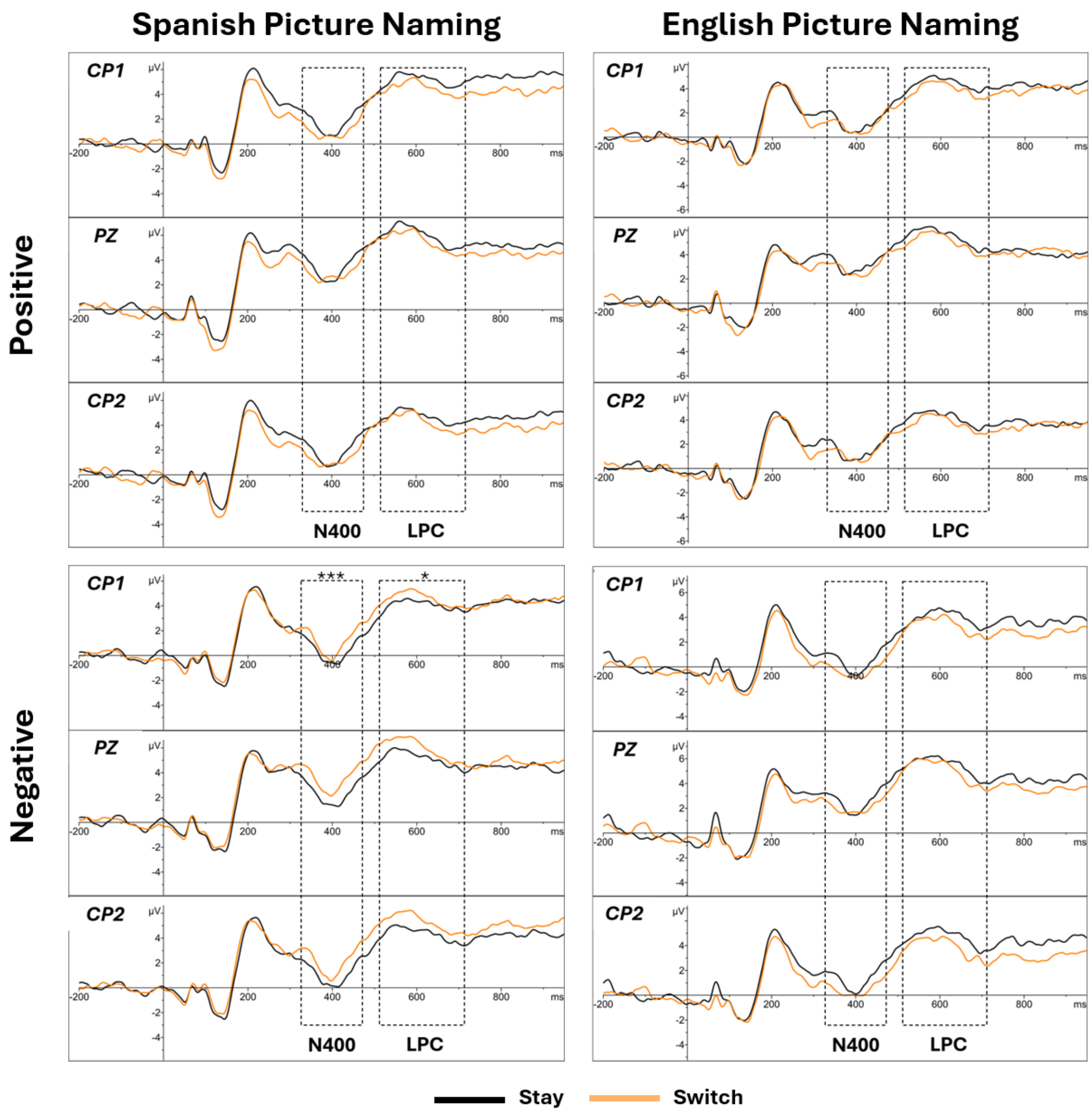


Figure 11. ERP Waveforms for the N400 and LPC Components by Emotion, Language, and Switching

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5. Discussion

The present study examined the temporal dynamics of emotional processing and its effect in bilingual language regulation. Spanish-English heritage bilinguals completed a cued-language switching picture naming task interleaved with emotion word classification trials. In regard to emotional processing, findings suggest that emotional processing may differ across the heritage language, Spanish, and societal language, English, but the observed differences were modulated by language experience. Regarding the influence of emotion on language switching, effects were observed in the electrophysiological data but not in behavioral outcomes. The effect of emotion on bilingual language regulation seems to carry across multiple levels of language processing and production as seen through different temporal ERP components.

5.1. Cross-Linguistic Differences in Emotional Processing

Emotional processing was observed through the behavioral and electrophysiological patterns that emerged during the word classification task, with language dominance playing an important role for both. In the behavioral data, greater English dominance was associated with reduced accuracy when classifying Spanish positive words relative to Spanish negative words as well as faster responses to English emotion words relative to Spanish emotion words. Previous studies have documented differences between positive and negative words in similar emotion word classification tasks. For example, Nasrallah et al. (2009) and Li and Wang (2022) found greater accuracy for negative than positive or neutral words and attributed this advantage to preferential allocation of attention toward negative information. In contrast, Ferré et al. (2018) found evidence of both positive facilitation and negative interference across affective and lexical decision tasks for both L1 and L2 words in early Catalan-Spanish bilinguals. They also tested a different group of unbalanced Spanish-English bilinguals and observed differences between language and emotional valence. Accuracy effects were particularly evident in the weaker L2 English with positive words being identified more accurately than negative and neutral words. Although the direction of the valence effect in the present study differs from that reported by Ferré et al., our findings and theirs suggest that emotional word processing is shaped by the relative status of a bilingual's languages and specifically when processing a weaker language. In the present sample, participants varied continuously in relative English to Spanish dominance, such that individuals at either end of the dominance continuum were more strongly dominant in one language than the other (unbalanced). The finding that valence effects varied as a function of this continuum therefore extends previous evidence from more unbalanced bilinguals by suggesting that relative language dominance may systematically modulate the behavioral consequences of emotional valence.

The other behavioral effect of language dominance emerged in reaction time between Spanish and English emotion words. As English dominance increased, the processing-speed difference between the two languages became larger in favor of English, such that more English dominant participant responded faster to English emotion words relative to Spanish. This finding may indicate that more English dominant participants experienced an advantage in processing speed for English emotion words. Since this effect did not differ by valence, it could be interpreted as a result of overall language processing speed (Thoma, 2024). Yet prior work suggests that language dominance can also shape the processing of emotional information. Vargas Fuentes et al. (2022), using the same BLP dominance measure used here, found that greater English dominance in Spanish heritage bilinguals was associated with a larger recognition advantage for taboo and negative English words relative to neutral words in a surprise recognition task. That study, however, did not examine whether dominance similarly affected emotional processing in the heritage language, Spanish. The present findings extend this work by showing that relative language dominance is associated with differential behavioral processing of English and Spanish emotional words. Furthermore, the emotional valence differences in accuracy observed in Spanish suggest that dominance may also shape emotional processing within the heritage language.

Evidence for cross-linguistic differences in emotional processing also emerged in the electrophysiological data. In the early ERP component of EPN, amplitudes did not significantly differ by language or emotional valence. The lack of language and emotional valence differences in the EPN do not necessarily indicate a lack of early emotional processing. The EPN is associated with early allocation of attentional resources and more negative amplitudes emerging when comparing emotionally salient information to neutral information (Schupp & Kirmse, 2021). The omission of neutral words in the current study could potentially explain the null effect of emotional valence. Following this logic, no language differences in the EPN suggest equal early emotional processing across the two languages regardless of dominance. For example, Herbert (2023) observed EPN sensitivity to emotional words in both L1 and L2 of late bilinguals, although the magnitude and lateralization of EPN responses differed across languages.

On the other hand, differences did emerge in the later LPC time window; specifically, when taking language dominance into account, a sensitivity to emotional valence in Spanish words appears in the later LPC window. Spanish negative words elicited more positive LPC amplitudes relative to Spanish positive words for more Spanish dominant participants. The differences in valence for Spanish words becomes statistically insignificant the farther participants leaned towards English dominance. Similar modulations of language aspects (e.g., proficiency, dominance) have been reported in previous studies.

Although not characterized as heritage speakers, Vélez-Uribe and Rosselli (2021) examined emotional word processing in Spanish-English bilinguals with similar profiles in age of acquisition to our sample population. Critically for our discussion, they grouped participants into balanced and unbalanced groups based on their self-rated proficiency. The groups differed in their Spanish proficiency but not in their English. They reported differences in EPN amplitudes by valence and language, but dominance effects emerged most critically in the LPC, with a three-way interaction between language, valence, and dominance. Balanced bilinguals showed relatively comparable valence effects across languages, whereas unbalanced bilinguals showed a distinct pattern in their less-proficient Spanish: positive words elicited the largest LPC amplitudes and negative words the smallest. The authors interpreted the attenuated LPC response to negative Spanish words as reflecting reduced emotional processing associated with lower Spanish proficiency.

The present LPC findings converge with Vélez-Uribe and Rosselli (2021) in demonstrating that language dominance modulates late emotional processing in a language-specific manner. There is a notable difference, however, in how language dominance is defined. In the present study, language dominance is not solely based on proficiency but also informed by other aspects such as language history, use and attitude (Birdsong et al., 2012). Therefore, the language differences we observed are not the result of processing a less proficient language but rather the relative dominance between the two. While Vélez-Uribe and Roselli found larger LPC amplitudes for Spanish positive words in the less Spanish proficient unbalanced group, we found larger LPC amplitudes for Spanish negative words when Spanish was the more dominant language; a pattern that has been found for L1 processing (e.g., Inaba et al., 2005).

Interestingly, we found no differences in LPC amplitudes for English positive and negative words. This lack of LPC differences is not necessarily indicative of a lack of emotional processing. The LPC reflects a later stage of processing featuring reanalysis, reconfiguration or reallocation of resources to process the emotion word. One possibility is that both positive and negative English words were processed faster than the LPC window could capture. This explanation aligns with the behavioral data where increased dominance in English was associated with faster responses to all English emotion words relative to Spanish. Since English is the dominant language in the environment, faster processing in English is not surprising.

Another possible explanation is that both negative and positive words elicited large LPC amplitudes due to the participants being highly sensitive to emotion words in their dominant language. Without the presence of a neutral baseline condition, it is hard to assess this claim. However, since no main effect of language was found, it seems like the LPC amplitudes were comparable between English and Spanish emotion words. According to traditional claims of L2 reduced emotional processing, LPC amplitudes should have been less pronounced in English. However, our findings do not align with these traditional claims and, instead, support a more dynamic and open system where emotional processing is influenced by experience both for the heritage and the societal language of heritage speakers.

Taken together, behavioral and electrophysiological patterns in the emotion word classification task suggest that differences in emotional processing across languages are dependent on relative dominance. Language dominance influenced processing for both the heritage language, Spanish, and the societal language, English. Yet, differences in emotional processing due to dominance emerge in later stages when semantic information is being monitored or evaluated (e.g., Tang et al., 2025, Véles-Uribe & Roselli, 2021).

5.2. Emotional Influences in Language Switching

Unlike the findings in emotional-processing, the behavioral and ERP results did not converge in the picture-naming analysis. Outcomes in accuracy and reaction time did not replicate previous findings on the effect of emotions on language switching (e.g., Liu et al., 2023; Wang et al., 2024; Liu et al., 2026a) nor did we replicate the results of Study 1 with positive words and longer responses in the emotion word trials being associated with longer naming latencies in picture naming trials. Although no effect was observed in the behavioral measures, distinct temporal patterns of emotional influence in language switching emerged in the electrophysiological data.

We replicated the findings of Liu et al. (2026a) in the N2 component. After positive words, switch trials showed larger negative amplitudes in the N2 relative to stay trials, whereas the difference in N2 amplitude between switch and stay trials was not significant after negative words. This effect was independent of language. Research on the N2 component has associated larger negative amplitudes as an early indicator of conflict resolution and engagement of inhibitory control (Verhoef et al., 2009; Jackson et al., 2001). In turn, studies looking into the effect of emotion on inhibition have found a facilitation effect following negative stimuli (e.g., Zinchenko et al., 2015). Pre-engaging inhibitory control seems to facilitate subsequent trials that may require inhibiting a nontarget response, as is the case with language switching. The documented relationship between negative stimuli and inhibitory control provides a viable pathway to explain the N2 findings.

Regarding the lack of an effect of language in the N2 emotion and switch interaction, there is mixed evidence for L1 and L2 differences. Some studies report N2 effects for switch trials with no difference between L1 and L2 (e.g., Zheng et al., 2020) while others have found asymmetrical switch costs reflected in N2 amplitudes (e.g., Christoffels et al., 2007). For example, Jackson et al. (2001) reported more negative N2 amplitudes for L2 switch trials than L2 stay trials, but no significant difference between switch and stay amplitudes for the L1. The present findings support that the effect of negative words on switching is language independent at least in the earlier stages of processing.

Cross-linguistic differences emerge when we look at the N400 and LPC components. The N400 is related to lexical and semantic processing during comprehension (Delogu et al., 2019) and production (Lau et al., 2009). The findings in language switching studies are mixed with some observing pronounced N400 after switch trials, others finding reduced N400 amplitudes after switch trials, and other reporting differences in language switch direction (see Hervais-Adelman et al. (2011) for a review). What is consistent in the literature is the interpretation of the N400 as a sensitive indicator to lexical-semantic processes involved in language switching. In particular, the cognitive effort of trying to access lexical items in the target language while dealing with the lexical interference of the previously used language. We observed more positive amplitudes in the N400 for switch trials preceded by negative words but only for Spanish. That is, after processing a negative word, switching to Spanish showed less pronounced N400 amplitudes. Wang et al. (2024) argue that the effect of negative words on language switching is characterized by constant inhibition that is distributed throughout the language switching process. Support for this argument comes from L2 switch trials eliciting larger amplitudes in a fearful mood condition. While the direction of the effect is opposite, larger vs smaller amplitudes in switch trials, our results align with negative words having a persisting effect throughout different stages of language switching production.

Our data also suggest an effect of emotions on switch trials in the LPC time window. Positive going amplitudes in later stages of processing have been associated with stimulus re-evaluation after lexical selection is completed. Following negative words, we found that Spanish switch trials elicited more positive LPC amplitudes relative to Spanish stay trials. Jackson et al. (2001)

also reported larger LPC amplitude after switch trials relative to stay trials. In a study with unbalanced Polis-English bilinguals, Naranowicz et al. (2022) observed enhanced LPC amplitudes for L2 in a meaningfulness judgement task when participants were induced in a negative mood. They suggest that this larger LPC reflects greater re-evaluation and regulation of negative information in L2. Taken together, the enhanced LPC observed here may reflect the combined demands of re-evaluating a response following a language switch and the lingering influence of negative emotional information, resulting in greater late-stage monitoring and re-analysis.

In summary, while behavior did not exhibit any effect of emotional processing on language switching, electrophysiological data analyzed through ERPs captured distinct effects of emotions on language switching at different time windows. After negative words, the N2 amplitudes in switch trials were not significantly different than stay trials whereas, after positive words, it was significant. The results of the N2 support previous findings on negative words reducing switch costs through the early engagement of inhibitory control. While this effect of negative words on N2 switch trial amplitudes was not contingent on language, later stages of processing showed distinctive results for Spanish switching. Following negative words, Spanish switch trials elicited more positive N400 and more positive LPC amplitudes relative to Spanish stay trials. These results highlight the persistent effect of negative words throughout language switching and how its language-specific interaction with lexical-semantic processing (N400) and later stages of response re-evaluation (LPC). We argue that these effects are observed in the heritage language, Spanish, due to regulatory demands of suppressing the residual activation of the more dominant language, English. In contrast, the absence of switch effects in English may reflect lower regulatory demands when switching into the more dominant language at least in terms of the need to inhibit a nontarget language, as residual activation of the less dominant Spanish language may have been resolved earlier in the language switching process.

6. Conclusion

The contributions of the present study ae two-fold. First, emotional processing in bilingual speakers is not constrained to purely L1 processing. Different sensitivities to emotional content for each language arise in both behavioral outcomes and for temporal courses in electrophysiological data. In particular, language differences emerge in later stages of word processing (LPC) which have been associated with late evaluation and monitoring of word selection. More importantly, language dominance seems to moderate the influence of language on emotional processing in bilingual speakers. Results in the EPN, however, showed no language nor emotional valence effect in ERP amplitudes. A possible explanation is the lack of a neutral baseline condition since EPN may reflect overall differences in emotionally salient vs neutral content. Future studies should include neutral words as a baseline to catch any potential effects in both behavior and ERP components. However, the lack of an overall effect of language indicates that the EPN amplitudes were comparable across the two languages.

Furthermore, the LPC findings suggest a modulation of language dominance on the heritage language, Spanish, but not for the societal language, English. The lack of LPC differences for emotional valence in English is not necessarily indicative of a lack or reduced emotional processing. LPC amplitudes for both negative and positive words in English may not differ because of an equal high sensitivity to emotions word in English in general. Nonetheless, it is hard to assess this claim without a neutral baseline. However, the lack of an overall main effect of language in the LPC may indicate that LPC amplitudes were sensitive to emotional content in both languages which aligns with the EPN results. Overall, these findings go against traditional claims of emotional processing being constrained or unchanged in the first acquired language. Instead, the findings in the present study suggest a more open system where emotional processing in each language is influenced by language experiences and not constrained to critical periods of age acquisition or just overall proficiency. The bilingual language system can be characterized as an open and dynamic system in which both languages remain active and continuously influence one another work (see Kroll et al. (2015) for a review). Contrary to traditional claims, emotions also form part of this open system.

Second, the current study expands research documenting the influence of emotions on bilingual language regulation. Although no effects were observed in behavior, ERP analyses revealed effects of emotion not seen in behavioral measures. Negative words had a lasting effect on the neural activation of components related to early engagement of inhibitory control, lexical-semantic processing and to later stages of monitoring and evaluation leading to word production. Importantly, the nature of this effect was not uniform across languages, with cross-linguistic differences emerging during later stages of processing. These findings suggest that emotion does not simply facilitate or hinder language switching. Instead, emotional information seems to interact with different cognitive and language mechanisms supporting language regulation at different points in time. The absence of behavioral effects highlights the value of ERPs for revealing temporally specific interactions between emotion and bilingual language regulation.

CHAPTER 5: General Conclusions

The goal of this dissertation was to examine the effect of emotion on bilingual language regulation as well as how bilingual experiences shape emotional processing in each language. Across two studies, we used a cued-language switching picture naming task with an interleaved emotion word task to investigate whether emotion influence language switching. The first study focused on the potential role of interactional context and language experience on this effect by comparing three groups of bilingual speakers. Meanwhile, the second study offers a temporal view into emotional processing and the influence of emotions on language switching through electrophysiological data.

The findings in Study 1 supported the claims of the Adaptive Control Hypothesis (Green & Abutalebi, 2003) by providing evidence of different sensitivity to language regulation demands across three groups of bilingual speakers. Behavioral indexes of language regulation, including reversed dominance, block order effects and mixing costs, differed not only by geographical location (US vs Mexico) but also within the two groups of US heritage speakers. Bilingual speakers within the same geographical location or community vary in terms of language use, frequency, and navigating different single vs dual-language use settings. Given the high variation not only across groups but also within groups, the results from this study should not be taken to reflect an effect of a single characteristic (e.g., geographical location, language pair, etc.) but rather as support for language experience and interactional demands shaping bilingual language regulation.

The findings across both studies further our understanding of the effect of emotion on language regulation. Although Study 1 did not replicate the behavioral findings of prior work on reduced switch costs after negative emotions, it provided other behavioral evidence of how emotions influence language processing. In particular, positive words and the speed of recognizing emotion words seemed to slow down naming production in both languages. However, these effects must be interpreted cautiously as we failed to replicate them across studies. The results of Study 2, on the other hand, did align with previous results on the effect of negative words on language switching although only in the electrophysiological data. ERP analyses showed an effect of negative words across multiple temporal stages associated with cognitive control, lexical-semantic processing and later re-evaluation in switch trials. Language seemed to modulate this effect at the later stages of processing, specifically for L2 switches during lexical processing and re-evaluation. These findings suggest that the influence of emotion can persist throughout the language switching process even when its consequences are not observed in behavior.

Finally, the findings from Study 2 highlight the bidirectional relationship between emotions and language in bilingual speakers. Just as emotions may influence bilingual language regulation, bilingual language experiences shape emotional processing. In Study 2, language dominance was found to moderate sensitivity to emotional valence in the LPC but not in the earlier EPN component. Specifically, differences emerged for the heritage language, Spanish, the more Spanish dominant participants reported to be. These findings suggest that cross-linguistic differences in emotional processing are not fixed between a bilingual's languages. This distinction is specifically important to heritage bilinguals whose experience is not always adequately characterized by traditional L1 vs L2 claims.

Future work on the effect of emotions on bilingual language regulation should consider how the effect may interact with different processes involved in language switching. In particular, the cross-linguistic difference that occurred in later stages of processing were found when switching to the heritage language, Spanish. Switching to a non-dominant language requires down regulating the residual activation of a dominant language. The effect of negative words on switching to Spanish may have persisted due to the need to continue inhibiting the dominant language, English. More empirical evidence is needed to test this claim. Studies using electrophysiological data with bilingual speakers with different language dominance might be especially useful.

In conclusion, emotions are an integral part of understanding how bilingual speakers process and regulate their languages. Emotional information seems to influence language switching through their shared reliance and engagement with cognitive control. Based on our findings, this influence unfolds across multiple processes involved in language switching and cross-linguistic influences emerge in later stages. At the same time, emotional processing is influenced by bilingual language experience which fights traditional claims of emotional processing being constrained to the first language. Emotions are also embedded within the open and dynamic bilingual system, where its influence can extend across languages rather than remaining confined to the language in which it is encountered.

REFERENCES

Abutalebi, J., & Green, D. W. (2008). Control mechanisms in bilingual language production: Neural evidence from language switching studies. *Language and cognitive processes*, *23*(4), 557-582.

Agudelo-Orjuela, P., de Vega, M., & Beltrán, D. (2021). Mutual influence between emotional language and inhibitory control processes. Evidence from an event-related potential study. *Psychophysiology, 58*(3), e13743.

Ahn, S., & Chang, C. B. (2022). Emotion word development in bilingual children living in majority and minority contexts. *Applied Linguistics*, *43*(5), 845-866.

Alcaide, N., & Ruiz, A. A. (2024). Language Switching as an Emotional Distancing Mechanism and its Implication for Health Behaviors: A Systematic Review. *Papeles del Psicólogo*, *45*(2), 91-98.

Antoniou, K. (2023). The ups and downs of bilingualism: A review of the literature on executive control using event-related potentials. *Psychonomic Bulletin & Review*, *30*(4), 1187-1226.

Balota, D. A., Yap, M. J., Hutchison, K. A., Cortese, M. J., Kessler, B., Loftis, B., ... & Treiman, R. (2007). The English lexicon project. *Behavior research methods*, *39*, 445-459.

Baron-Cohen, S., Golan, O., Wheelwright, S., & Granader, Y. (2010). Emotion word comprehension from 4 to 16 years old: a developmental survey. *Frontiers in evolutionary neuroscience*, *2*, 109.

Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R. H. B., Singmann, H., ... & Bolker, M. B. (2015). Package 'lme4'. *convergence*, *12*(1), 2.

Beatty-Martínez, A. L., Navarro-Torres, C. A., Dussias, P. E., Bajo, M. T., Guzzardo Tamargo, R. E., & Kroll, J. F. (2020). Interactional context mediates the consequences of bilingualism for language and cognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *46*(6), 1022.

Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition, 112*(3), 494-500.

Bice, K., & Kroll, J. F. (2019). English only? Monolinguals in linguistically diverse contexts have an edge in language learning. *Brain and language*, *196*, 104644.

Bice, K., & Kroll, J. F. (2021). Grammatical processing in two languages: How individual differences in language experience and cognitive abilities shape comprehension in heritage bilinguals. *Journal of Neurolinguistics*, *58*, 100963.

Birdsong, D., Gertken, L. M., & Amengual, M. (2012). Bilingual language profile: An easy-to-use instrument to assess bilingualism. *COERLL, University of Texas at Austin*.

Blanco, C. P., Bannard, C., & Smiljanic, R. (2016). Differences in the association between segment and language: early bilinguals pattern with monolinguals and are less accurate than late bilinguals. *Frontiers in Psychology*, *7*, 993. doi: 10.3389/fpsyg.2016.00993

Borjian, A. (2015). Learning English in Mexico: Perspectives from Mexican teachers of English. *The CATESOL journal*, *27*(1), 163-173.

Branzi, F. M., Martin, C. D., Abutalebi, J., & Costa, A. (2014). The after-effects of bilingual language production. *Neuropsychologia*, *52*, 102-116.

Braver, T. S. (2012). The variable nature of cognitive control: a dual mechanisms framework. *Trends in cognitive sciences*, *16*(2), 106-113.

Bultena, S., Dijkstra, T., & Van Hell, J. G. (2015). Language switch costs in sentence comprehension depend on language dominance: Evidence from self-paced reading. *Bilingualism: Language and Cognition, 18*(3), 453-469.

Caldwell-Harris, C. L., & MacWhinney, B. (2023). Age effects in second language acquisition: Expanding the emergentist account. *Brain and language*, *241*, 105269.

California Immigrant Data Portal. (2021). *Languages spoken*. <Website> https://immigrantdataca.org/indicators/languages-spoken?breakdown=top-languages&geo=02000000000006000&immig=2

Cargnelutti, E., Tomasino, B., & Fabbro, F. (2019). Language brain representation in bilinguals with different age of appropriation and proficiency of the second language: A meta-analysis of functional imaging studies. *Frontiers in human neuroscience*, *13*, 154. doi: 10.3389/fnhum.2019.00154

Carreira, M. M. (2018). Towards a national strategy for capacity-building in heritage languages and Spanish: A response to America's languages: Investing in language education for the 21st century. *Hispania*, *101*(1), 5-9.

Chang, J. H., Kuo, C. Y., Huang, C. L., & Lin, Y. C. (2018). The flexible effect of mindfulness on cognitive control. *Mindfulness*, *9*(3), 792-800.

Chen, P., Lin, J., Chen, B., Lu, C., & Guo, T. (2015). Processing emotional words in two languages with one brain: ERP and fMRI evidence from Chinese–English bilinguals. *Cortex*, *71*, 34-48.

Christoffels, I. K., Firk, C., & Schiller, N. O. (2007). Bilingual language control: An event-related brain potential study. *Brain research*, *1147*, 192-208.

Cieślicka, A. B., & Guerrero, B. L. (2023). Emotion Word Processing in Immersed Spanish-English/English-Spanish Bilinguals: An ERP Study. *Languages*, *8*(1), 42. https://doi.org/10.3390/languages8010042

Circi, R., Gatti, D., Russo, V., & Vecchi, T. (2021). The foreign language effect on decision-making: A meta-analysis. *Psychonomic Bulletin & Review*, 1-11.

Citron, F. M., Weekes, B. S., & Ferstl, E. C. (2013). Effects of valence and arousal on written word recognition: Time course and ERP correlates. *Neuroscience letters*, *533*, 90-95.

Conrad, M., Recio, G., & Jacobs, A. M. (2011). The time course of emotion effects in first and second language processing: A cross cultural ERP study with German–Spanish bilinguals. *Frontiers in psychology*, *2*, 351.

Costa, A., & Santesteban, M. (2004). Lexical access in bilingual speech production: Evidence from language switching in highly proficient bilinguals and L2 learners. *Journal of memory and Language*, *50*(4), 491-511.

Declerck, M., & Koch, I. (2022). *The concept of inhibition in bilingual control.* Psychological Review, 130, 953–976.

Declerck, M., Kleinman, D., & Gollan, T. H. (2020). Which bilinguals reverse language dominance and why?. *Cognition*, *204*, 104384.

Declerck, M., Meade, G., Midgley, K. J., Holcomb, P. J., Roelofs, A., & Emmorey, K. (2021). Language control in bimodal bilinguals: Evidence from ERPs. *Neuropsychologia*, *161*, 108019.

Declerck, M., Philipp, A. M., & Koch, I. (2013). Bilingual control: sequential memory in language switching. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(6), 1793.

Delogu, F., Brouwer, H., & Crocker, M. W. (2019). Event-related potentials index lexical retrieval (N400) and integration (P600) during language comprehension. *Brain and cognition*, *135*, 103569.

Derakhshan, A., & Karimi, E. (2015). The interference of first language and second language acquisition. *Theory and Practice in language studies*, *5*(10), 2112-2117.

Dewaele, J. M. (2004). The emotional force of swearwords and taboo words in the speech of multilinguals. *Journal of multilingual and multicultural development*, *25*(2-3), 204-222.

Dewaele, J. M. (2006). Perceived language dominance and language preference for emotional speech: The implications for attrition research. In *First language attrition: Interdisciplinary perspectives on methodological issues* (pp. 81-104). John Benjamins Publishing Company.

Dewaele, J. M. (2008). The emotional weight of I love you in multilinguals' languages. *Journal of Pragmatics*, *40*(10), 1753-1780.

Dewaele, J. M. (2011). Reflections on the emotional and psychological aspects of foreign language learning and use. *Anglistik: International journal of English studies*, *22*(1), 23-42.

Douglas Bates, Martin Maechler, Ben Bolker, Steve Walker (2015). Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 1-48. doi:10.18637/jss.v067.i01.

Dubé, D., & Thordardottir, E. (2024). Using semantic verbal fluency to estimate the relative and absolute vocabulary size of bilinguals: An exploratory study of children and adolescents. *Journal of Communication Disorders*, *111*, 106450.

Duñabeitia, J. A., Baciero, A., Antoniou, K., Antoniou, M., Ataman, E., Baus, C., ... & Pliatsikas, C. (2022). The multilingual picture database. *Scientific data*, *9*(1), 431.

Eisenberg, N., Sadovsky, A., & Spinrad, T. L. (2005). Associations of emotion‐related regulation with language skills, emotion knowledge, and academic outcomes. *New directions for child and adolescent development*, *2005*(109), 109-118.

Fan, L., Xu, Q., Wang, X., Zhang, F., Yang, Y., & Liu, X. (2016). Neural correlates of task-irrelevant first and second language emotion words–evidence from the emotional face–word Stroop task. *Frontiers in psychology*, *7*, 220614.

Ferré, P., Anglada-Tort, M., & Guasch, M. (2018). Processing of emotional words in bilinguals: Testing the effects of word concreteness, task type and language status. *Second Language Research*, *34*(3), 371-394.

Fox J, Weisberg S (2019). _An R Companion to Applied Regression_, Third edition. Sage, Thousand Oaks CA. <https://www.john-fox.ca/Companion/>.

Gade, M., Declerck, M., Philipp, A. M., Rey-Mermet, A., & Koch, I. (2021). Assessing the Evidence for Asymmetrical Switch Costs and Reversed Language Dominance Effects – A Meta-Analysis. *Journal of Cognition, 4*(1): 55, pp. 1–32. DOI: https://doi.org/10.5334/joc.186

Garcia, O., Faghihi, N., Raola, A. R., & Vaid, J. (2021). Factors influencing bilinguals' speed and accuracy of number judgments across languages: A meta-analytic review. *Journal of Memory and Language*, *118*, 104211.

Gavino, M. F., Malul, T., Prior, A., Degani, T., & Gollan, T. H. (2025). Competition for selection drives the nature of bilingual language control: Picture naming, but not reading aloud, triggers global inhibition of the dominant language. *Cognition*, *265*, 106260.

Geipel, J., Hadjichristidis, C., & Surian, L. (2015). How foreign language shapes moral judgment. *Journal of experimental social psychology*, *59*, 8-17.

Goldrick, M., & Gollan, T. H. (2023). Inhibitory control of the dominant language: Reversed language dominance is the tip of the iceberg. *Journal of Memory and Language*, 130, 104410. APA PsycNet. [1, 2]

Grainger, J., Midgley, K., & Holcomb, P. J. (2010). Re-thinking the bilingual interactive-activation model from a developmental perspective (BIA-d). In M. Kail & M. Hickmann (Eds.), Language Acquisition across Linguistic and Cognitive Systems.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and cognition*, *1*(2), 67-81.

Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of cognitive psychology*, *25*(5), 515-530.

Green, P., & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, *7*(4), 493-498.

Gross, J. J. (1999). Emotion and emotion regulation. *Handbook of personality: Theory and research*, *2*, 525-552.

Gullifer, J. W., & Titone, D. (2020). Characterizing the social diversity of bilingualism using language entropy. *Bilingualism: Language and cognition*, *23*(2), 283-294.

Gullifer, J. W., Chai, X. J., Whitford, V., Pivneva, I., Baum, S., Klein, D., & Titone, D. (2018). Bilingual experience and resting-state brain connectivity: Impacts of L2 age of acquisition and social diversity of language use on control networks. *Neuropsychologia*, *117*, 123-134.

Han, X., Li, W., & Filippi, R. (2022). The effects of habitual code-switching in bilingual language production on cognitive control. *Bilingualism: Language and Cognition*, *25*(5), 869-889.

Harris, C. L. (2004). Bilingual speakers in the lab: Psychophysiological measures of emotional reactivity. *Journal of multilingual and multicultural development*, *25*(2-3), 223-247.

Harris, C. L., Ayçíçeğí, A., & Gleason, J. B. (2003). Taboo words and reprimands elicit greater autonomic reactivity in a first language than in a second language. *Applied psycholinguistics*, *24*(4), 561-579.

Harris, C. L., Gleason, J. B., & Aycicegi, A. (2006). When is a first language more emotional? Psychophysiological evidence from bilingual speakers. *Bilingual education and bilingualism*, *56*, 257-283. https://doi.org/10.21832/9781853598746-012

Hayakawa, S., Tannenbaum, D., Costa, A., Corey, J. D., & Keysar, B. (2017). Thinking more or feeling less? Explaining the foreign-language effect on moral judgment. *Psychological science*, *28*(10), 1387-1397.

Hendricks, M. A., & Buchanan, T. W. (2016). Individual differences in cognitive control processes and their relationship to emotion regulation. *Cognition and Emotion*, *30*(5), 912-924.

Herbert, C. (2023). Early, emotional and embodied? Processing of emotional words and body words in the native and a second language–evidence from early event-related brain potential modulation and rapid serial visual presentation. *Language, Cognition and Neuroscience*, *38*(10), 1384-1411.

Hernández-Santacruz, J., Torres, J., & Kroll, J. F. (2026). Heritage speakers reveal the dynamics of bilingual language regulation. *Bilingualism: Language and cognition*, *29*(1), 78-91.

Hinojosa, J. A., Fernández-Folgueiras, U., Albert, J., Santaniello, G., Pozo, M. A., & Capilla, A. (2017). Negative induced mood influences word production: An event-related potentials study with a covert picture naming task. *Neuropsychologia*, *95*, 227-239.

Holmes, K. J., Kassin, L., Buchillon-Almeida, D., & Canseco-Gonzalez, E. (2024). Emotion regulation elicits cross-linguistically shared and language-specific forms of linguistic distancing. *Scientific Reports*, *14*(1), 22605.

Hoque, E. (2017). An introduction to the second language acquisition. *Language Acquisition*, 1-23.

Hsu, N. S., & Novick, J. M. (2016). Dynamic engagement of cognitive control modulates recovery from misinterpretation during real-time language processing. *Psychological science*, *27*(4), 572-582.

Inaba, M., Nomura, M., & Ohira, H. (2005). Neural evidence of effects of emotional valence on word recognition. *International Journal of Psychophysiology*, *57*(3), 165-173.

Inzlicht, M., Bartholow, B. D., & Hirsh, J. B. (2015). Emotional foundations of cognitive control. *Trends in cognitive sciences*, *19*(3), 126-132.

Jackson, G. M., Swainson, R., Cunnington, R., & Jackson, S. R. (2001). ERP correlates of executive control during repeated language switching. Bilingualism: Language and cognition, 4(2), 169-178.

Jackson, J. C., Watts, J., Henry, T. R., List, J. M., Forkel, R., Mucha, P. J., ... & Lindquist, K. A. (2019). Emotion semantics show both cultural variation and universal structure. *Science*, *366*(6472), 1517-1522.

Jankowiak, K., & Korpal, P. (2018). On modality effects in bilingual emotional language processing: Evidence from galvanic skin response. *Journal of psycholinguistic research*, *47*(3), 663-677.

Jiang, S., Ma, L., & Chen, B. (2024). The role of cognitive control in bilingual language comprehension: An event-related potential study of dense code-switching sentences. *Bilingualism: Language and Cognition, 27*(1), 137-153.

Kalia, V., Wilbourn, M. P., & Ghio, K. (2014). Better early or late? Examining the influence of age of exposure and language proficiency on executive function in early and late bilinguals. *Journal of Cognitive Psychology*, *26*(7), 699-713.

Kang, C., Ma, F., Li, S., Kroll, J. F., & Guo, T. (2020). Domain-general inhibition ability predicts the intensity of inhibition on non-target language in bilingual word production: An ERP study. *Bilingualism: Language and Cognition*, *23*(5), 1056-1069.

Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words?. *Memory & cognition*, *31*(8), 1169-1180.

Keysar, B., Hayakawa, S. L., & An, S. G. (2012). The foreign-language effect: Thinking in a foreign tongue reduces decision biases. *Psychological science*, *23*(6), 661-668.

Kroll, J. F. (2024). The bilingual mental lexicon. In *The Routledge Handbook of Second Language Acquisition, Morphosyntax, and Semantics* (pp. 47-60). Routledge.

Kroll, J. F., & Ma, F. (2017). The bilingual lexicon. *The handbook of psycholinguistics*, 294-319.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of memory and language*, *33*(2), 149-174.

Kroll, J. F., Dussias, P. E., Bice, K., & Perrotti, L. (2015). Bilingualism, mind, and brain. *Annu. Rev. Linguist.*, *1*(1), 377-394.

Kron, A., Schul, Y., Cohen, A., & Hassin, R. R. (2010). Feelings don't come easy: Studies on the effortful nature of feelings. *Journal of Experimental Psychology: General, 139*(3), 520–534. https://doi.org/10.1037/a0020008

Kuhl, P. K. (2010). Brain mechanisms in early language acquisition. *Neuron*, *67*(5), 713-727.

Kuznetsova A, Brockhoff PB, Christensen RHB (2017). “lmerTest Package: Tests in Linear Mixed Effects Models.” _Journal of Statistical Software_, *82*(13), 1-26. doi:10.18637/jss.v082.i13 <https://doi.org/10.18637/jss.v082.i13>.

Kyriakou, A., Mavrou, I., & Palapanidi, K. (2024). The role of foreign language in the experience and emotional expression of guilt: Evidence from moral scenarios and autobiographical memories of bilinguals. *International Journal of Bilingual Education and Bilingualism*, *27*(10), 1407-1421.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics:(de) constructing the N400. *Nature reviews neuroscience*, *9*(12), 920-933.

Lau, E., Almeida, D., Hines, P. C., & Poeppel, D. (2009). A lexical basis for N400 context effects: Evidence from MEG. *Brain and language*, *111*(3), 161-172.

Lee, T. (2013). Variation among heritage speakers: Sequential vs. simultaneous bilinguals. *Journal of the National Council of Less Commonly Taught Languages*, *14*, 1-26.

Lenth, R. (2023). emmeans: Estimated Marginal Means, aka Least-Squares Means_. *R package version 1.8. 5*.

Li, C., & Gollan, T. H. (2022). Language-switch costs from comprehension to production might just be task-switch costs. *Bilingualism: Language and cognition*, *25*(3), 459-470.

Li, D., & Wang, X. (2022). Can ambient odors influence the recognition of emotional words? A behavioral and event-related potentials study. *Cognitive Neurodynamics*, *16*(3), 575-590.

Linck, J. A., Kroll, J. F., & Sunderman, G. (2009). Losing access to the native language while immersed in a second language: Evidence for the role of inhibition in second-language learning. *Psychological science*, *20*(12), 1507-1515.

Liu, H., Kong, C., de Bruin, A., Wu, J., & He, Y. (2020). Interactive influence of self and other language behaviors: Evidence from switching between bilingual production and comprehension. *Human Brain Mapping*, *41*(13), 3720-3736.

Liu, H., Liu, W., Schwieter, J. W., & Wu, Y. J. (2023). How processing emotion affects language control in bilinguals. *Brain Structure and Function*, *228*(2), 635-649.

Liu, S., Liu, D., Huang, J., Liu, L., Schwieter, J. W., & Chen, B. (2026a). How emotional states modulate cognitive control strategies across language-switching contexts. *Bilingualism: Language and Cognition*, 1-15.

Liu, W., Liu, H., Xing, Z., & Schwieter, J. W. (2026b). Emotional words differentially influence language control in bilinguals: An fMRI study. *Acta Psychologica*, *269*, 107500.

Liu, Y., Chang, S., Li, L., Liu, W., Chen, D., Zhang, J., & Wang, R. (2018). Effects of naming language and switch predictability on switch costs in bilingual language production. *Frontiers in Psychology*, *9*, 649.

López, B. G., Lezama, E., & Heredia Jr, D. (2019). Language brokering experience affects feelings toward bilingualism, language knowledge, use, and practices: A qualitative approach. *Hispanic Journal of Behavioral Sciences*, *41*(4), 481-503.

Luk, G., De Sa, E. R. I. C., & Bialystok, E. (2011). Is there a relation between onset age of bilingualism and enhancement of cognitive control?. *Bilingualism: Language and cognition*, *14*(4), 588-595.

Marian, V., & Kaushanskaya, M. (2008). Words, feelings, and bilingualism: Cross-linguistic differences in emotionality of autobiographical memories. *The mental lexicon*, *3*(1), 72-91.

McLaughlin, J., Osterhout, L., & Kim, A. (2004). Neural correlates of second-language word learning: Minimal instruction produces rapid change. *Nature neuroscience*, *7*(7), 703-704.

Meuter, R. F., & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. *Journal of Memory and Language*, 40(1), 25–40. [1, 2]

Mishra, K. A., & Asthana, H. S. (2026). Language dominance effects on bilingual children: investigating language switching among native Hindi speakers using picture-naming. *Cognitive Processing*, 1-12.

Misra, M., Guo, T., Bobb, S. C., & Kroll, J. F. (2012). When bilinguals choose a single word to speak: Electrophysiological evidence for inhibition of the native language. *Journal of Memory and language, 67*(1), 224-237.

Morales, J., Gómez-Ariza, C. J., & Bajo, M. T. (2013). Dual mechanisms of cognitive control in bilinguals and monolinguals. *Journal of Cognitive Psychology*, *25*(5), 531-546.

Morrison, C., & Taler, V. (2023). ERP differences between monolinguals and bilinguals: The role of linguistic distance. *Bilingualism: Language and cognition*, *26*(2), 293-306.

Naranowicz, M., Jankowiak, K., Kakuba, P., Bromberek-Dyzman, K., & Thierry, G. (2022). In a bilingual mood: Mood affects lexico-semantic processing differently in native and non-native languages. *Brain Sciences*, *12*(3), 316.

Nasrallah, M., Carmel, D., & Lavie, N. (2009). Murder, she wrote: enhanced sensitivity to negative word valence. *Emotion*, *9*(5), 609.

Noguera, C. V., Villar, C. M., & Mavrou, I. (2022). Seething with rage: Affective vocabulary of anger in autobiographical memories of Spanish-German bilinguals. In *Recent advances in second language emotion research* (pp. 155-189). Thomson Reuters-Civitas.

Olson, D. J. (2016). The gradient effect of context on language switching and lexical access in bilingual production. *Applied Psycholinguistics*, *37*(3), 725-756.

Olson, D. J. (2017). Bilingual language switching costs in auditory comprehension. *Language, Cognition and Neuroscience*, *32*(4), 494-513.

Parada, M. (2013). Sibling variation and family language policy: The role of birth order in the Spanish proficiency and first names of second-generation Latinos. *Journal of Language, Identity & Education*, *12*(5), 299-320.

Pavlenko, A. (2005). *Emotions and multilingualism*. Cambridge University Press.

Pavlenko, A. (2012). Affective processing in bilingual speakers: Disembodied cognition?. *International Journal of Psychology*, *47*(6), 405-428.

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature reviews neuroscience*, *9*(2), 148-158.

Pruessner, L., Barnow, S., Holt, D. V., Joormann, J., & Schulze, K. (2020). A cognitive control framework for understanding emotion regulation flexibility. *Emotion*, *20*(1), 21-29.

Psychology Software Tools, Inc. [E-Prime Go]. (2020). Retrieved from https://support.pstnet.com/.

Purpuri, S., Vasta, N., Filippi, R., Wei, L., & Mulatti, C. (2025). Does language shape the way we think? A review of the foreign language effect across domains. *International Journal of Bilingualism*, *29*(1), 269-291.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for statistical Computing, Vienna, Austria. Retrieved from https://www.R-project.org/.

R Core Team (2026). _R: A Language and Environment for Statistical Computing_. R Foundation for Statistical Computing, Vienna, Austria. doi:10.32614/R.manuals <https://doi.org/10.32614/R.manuals>. <https://www.R-project.org/>.

Rodriguez-Fornells, A., Kramer, U., Lorenzo-Seva, U., & Münte, T. F. (2012). Self-assessment of individual differences in language switching. *Frontiers in psychology*, *2*, 11463.

Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124*(2), 207–231.

Sabater, L., Guasch, M., Ferré, P., Fraga, I., & Hinojosa, J. A. (2020). Spanish affective normative data for 1,406 words rated by children and adolescents (SANDchild). *Behavior Research Methods*, *52*, 1939-1950.

Schmidt, S. R., & Schmidt, C. R. (2016). The emotional carryover effect in memory for words. *Memory*, *24*(7), 916-938.

Schupp, H. T., & Kirmse, U. M. (2021). Case-by-case: Emotional stimulus significance and the modulation of the EPN and LPP. *Psychophysiology*, *58*(4), e13766.

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2003). Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. *Neuroreport*, *14*(8), 1107-1110.

Schwarz, G. (1978). Estimating the dimension of a model. *The annals of statistics*, 461-464.

Shen, Y. (2016). The impacts of the influx of new foreign undergraduate students on US higher education. *Journal of Economic Literature*.

Shishkin, E., & Ecke, P. (2018). Language Dominance, Verbal Fluency, and Language Control in two Groups of Russian–English Bilinguals. *Languages*, *3*(3), 27. https://doi.org/10.3390/languages3030027

Streubel, B., Gunzenhauser, C., Grosse, G., & Saalbach, H. (2020). Emotion-specific vocabulary and its contribution to emotion understanding in 4-to 9-year-old children. *Journal of experimental child psychology*, *193*, 104790.

Szekely, A., Jacobsen, T., D'Amico, S., Devescovi, A., Andonova, E., Herron, D., ... & Bates, E. (2004). A new on-line resource for psycholinguistic studies. *Journal of memory and language*, *51*(2), 247-250.

Tang, D., Li, X., Fu, Y., Wang, H., Li, X., Parviainen, T., & Kärkkäinen, T. (2025). Neural correlates of emotion-label vs. emotion-laden word processing in late bilinguals: evidence from an ERP study. *Cognition and Emotion*, *39*(7), 1576-1593.

Thoma, D. (2021). Emotion regulation by attentional deployment moderates bilinguals' language-dependent emotion differences. *Cognition and Emotion*, *35*(6), 1121-1135.

Thoma, D. (2024). Language-dependent emotions in heritage and second language bilinguals: When physiological reactions deviate from feelings. *International Journal of Bilingualism*, *28*(3), 374-389.

Timmer, K., Christoffels, I. K., & Costa, A. (2019). On the flexibility of bilingual language control: The effect of language context. *Bilingualism: Language and Cognition*, *22*(3), 555-568.

Timmer, K., Wolna, A., & Wodniecka, Z. (2025). The impact of cues on language switching: do spoken questions reduce the need for bilingual language control?. *Bilingualism: Language and cognition*, *28*(3), 697-715.

Timofeeva, P., Quiñones, I., Geng, S., de Bruin, A., Carreiras, M., & Amoruso, L. (2023). Behavioral and oscillatory signatures of switch costs in highly proficient bilinguals. *Scientific reports*, *13*(1), 7725. https://doi.org/10.1038/s41598-023-34895-1

Toivo, W., Scheepers, C., & Dewaele, J.-M. (2024). RER-LX: A new scale to measure reduced emotional resonance in bilinguals' later learnt language. *Bilingualism: Language and Cognition*, *27*(3), 434–446. doi:10.1017/S1366728923000561

Valdés, G. (2014). Heritage Language Students: Profiles and Possibilities1. In *Handbook of Heritage, Community, and Native American Languages in the United States* (pp. 27-35). Routledge.

van den Berg, F., Brouwer, J., Tienkamp, T. B., Verhagen, J., & Keijzer, M. (2022). Language entropy relates to behavioral and pupil indices of executive control in young adult bilinguals. *Frontiers in Psychology*, *13*, 864763.

Vargas Fuentes, N. A., Kroll, J. F., & Torres, J. (2022). What heritage bilinguals tell us about the language of emotion. *Languages*, *7*(2), 144.

Vélez-Uribe, I., & Rosselli, M. (2021). Electrophysiological correlates of emotion word processing in Spanish–English bilinguals. *Bilingualism: Language and Cognition*, *24*(1), 31-55.

Verhoef, K., Roelofs, A., & Chwilla, D. J. (2009). Role of inhibition in language switching: Evidence from event-related brain potentials in overt picture naming. *Cognition*, *110*(1), 84-99.

Vos, D. M., Riès, S., Vanderperren, K., Vanrumste, B., Alario, F. X., Huffel, V. S., & Burle, B. (2010). Removal of muscle artifacts from EEG recordings of spoken language production. *Neuroinformatics*, *8*, 135-150.

Wang, D., Chen, S., Qin, Y., Wang, S., & Hou, R. (2026). Asymmetric Language Switch Benefits From Comprehension to Production in Chinese Learners of English as a Foreign Language (EFL): Rethinking Cross-Modality Language Control. *International Journal of Bilingualism*, 13670069261456515.

Wang, W., Qi, M., & Gao, H. (2021). An ERP investigation of the working memory stroop effect. *Neuropsychologia*, *152*, 107752.

Wang, Y. M., Chen, J., & Han, B. Y. (2017). The effects of cognitive reappraisal and expressive suppression on memory of emotional pictures. *Frontiers in Psychology*, *8*, 1921.

Wang, Y., Liu, X., Liu, D., & Zhu, C. (2024). Language switching is modulated by emotion priming: evidence from behavioral and event-related potentials study. *Frontiers in Psychology*, *15*, 1373636.

Weimer, A., Koniakowsky, I., Nazir, T. A., & Huckauf, A. (2022). Behavioral evidence for differences in emotional resonance during processing first and second language. *International Journal of Bilingualism*, *26*(6), 784-798.

White, K. K., Abrams, L., LaBat, L. R., & Rhynes, A. M. (2016). Competing influences of emotion and phonology during picture-word interference. *Language, Cognition and Neuroscience*, *31*(2), 265-283.

Williams, A. I., Rochanavibhata, S., & Marian, V. (2026). Language-dependent expression of anxiety and depression symptoms in Japanese-English bilinguals. *Clinical Psychological Science*, 21677026251385547.

Xie, Z., & Antolovic, K. (2022). Differential impacts of natural L2 immersion and intensive classroom L2 training on cognitive control. *Quarterly Journal of Experimental Psychology*, *75*(3), 550-562.

Xie, Z., & Dong, Y. (2021). Influence of the study abroad bilingual experience on cognitive control among young adults. *International Journal of Bilingualism*, *25*(5), 1417-1428.

Xing, A. (2021). Foreign language effect on risk preference: The framing effect, loss aversion, and risk aversion. *Journal of Behavioral and Experimental Economics*, *93*, 101723.

Yao, Z., Yu, D., Wang, L., Zhu, X., Guo, J., & Wang, Z. (2016). Effects of valence and arousal on emotional word processing are modulated by concreteness: Behavioral and ERP evidence from a lexical decision task. *International Journal of Psychophysiology*, *110*, 231-242.

Yow, W. Q., & Li, X. (2015). Balanced bilingualism and early age of second language acquisition as the underlying mechanisms of a bilingual executive control advantage: Why variations in bilingual experiences matter. *Frontiers in psychology*, *6*, 164.

Zhang, D., He, W., Wang, T., Luo, W., Zhu, X., Gu, R., ... & Luo, Y. J. (2014). Three stages of emotional word processing: an ERP study with rapid serial visual presentation. *Social cognitive and affective neuroscience*, *9*(12), 1897-1903.

Zhang, H., Diaz, M. T., Guo, T., & Kroll, J. F. (2021). Language immersion and language training: Two paths to enhanced language regulation and cognitive control. *Brain and Language*, *223*, 105043.

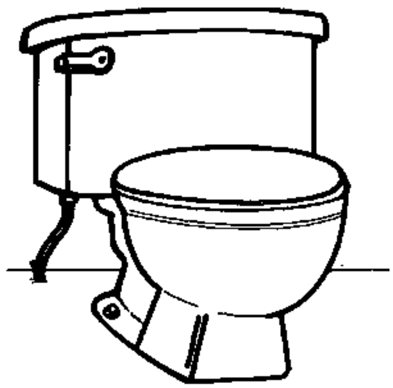
Zhang, W., Jończyk, R., Wu, Y. J., Lan, Y., Gao, Z., Hu, J., ... & Gao, S. (2023). Brain potentials reveal how emotion filters native language access when bilinguals read words in their second language. *Cerebral Cortex*, *33*(13), 8783-8791.

Zheng, X., Roelofs, A., Erkan, H., & Lemhöfer, K. (2020). Dynamics of inhibitory control during bilingual speech production: An electrophysiological study. *Neuropsychologia*, *140*, 107387.

Zheng, X., Roelofs, A., Erkan, H., & Lemhöfer, K. (2020). Dynamics of inhibitory control during bilingual speech production: An electrophysiological study. *Neuropsychologia*, *140*, 107387.

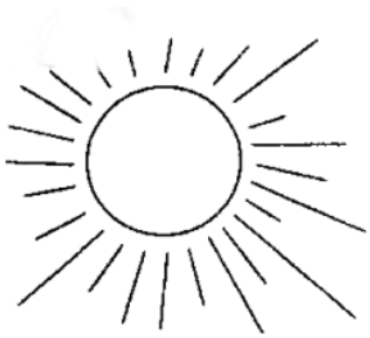
APPENDIX A: Samples of Picture Naming Images

Below are sample pictures for the picture naming task and its corresponding dominant name in English.



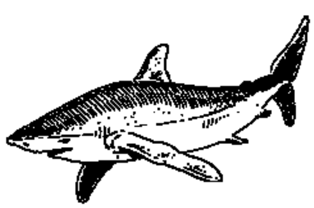
Toilet

Stroller



Sun

Spoon



Shark

Ring

APPENDIX B: List of Words in Emotion Word Classification Task

Below are the words for Study 1 and 2 with Spanish-English bilinguals

English		Spanish	
Negative	Positive	Negative	Positive
1. Knife	1. Luck	1. Cuchillo	1. Suerte
2. Hell	2. Friend	2. Infierno	2. Amigo
3. Death	3. Smile	3. Muerte	3. Sonrisa
4. Danger	4. Gift	4. Peligro	4. Regalo
5. War	5. Sunset	5. Guerra	5. Atardecer
6. Scar	6. Beauty	6. Cicatríz	6. Belleza
7. Earthquake	7. Kiss	7. Terremoto	7. Beso
8. Trash	8. Party	8. Basura	8. Fiesta

Below are the words for Study 1 with Mandarin-English Bilinguals

English		Mandarin	
Negative	Positive	Negative	Positive
1. rubbish	1. flower	1. 垃圾	1. 鲜花
2. scar	2. rose	2. 伤疤	2. 玫瑰
3. prison	3. rainbow	3. 监狱	3. 彩虹
4. flood	4. smile	4. 洪水	4. 笑容
5. earthquake	5. holiday	5. 地震	5. 假期
6. shit	6. mother	6. 粪便	6. 妈妈
7. war	7. sunshine	7. 战争	7. 阳光
8. death	8. angel	8. 死亡	8. 天使

APPENDIX C: Pairwise comparisons of Block types in each Language and Group (Picture Naming Accuracy)

Group	Language	Block	OR	SE	95 % CI Lower Bound	95 % CI Upper Bound
Spanish Late Bilingual (Mexico)	English	Pure (English First) / Pure (Other First)	0.78	0.12	0.55	1.11
Spanish Late Bilingual (Mexico)	English	Pure (English First) / Mixed	0.90	0.10	0.96	1.16
Spanish Late Bilingual (Mexico)	English	Pure (Other First) / Mixed	1.145	0.14	0.87	1.52
Spanish Late Bilingual (Mexico)	Spanish	Pure (English First) / Pure (Other First)	0.56 *	0.13	0.32	0.99
Spanish Late Bilingual (Mexico)	Spanish	Pure (English First) / Mixed	1.35	0.21	0.93	1.96
Spanish Late Bilingual (Mexico)	Spanish	Pure (Other First) / Mixed	2.39 ***	0.49	1.45	3.90
Mandarin Heritage (US)	English	Pure (English First) / Pure (Other First)	0.77	0.15	0.49	1.24
Mandarin Heritage (US)	English	Pure (English First) / Mixed	0.83	0.12	0.59	1.16
Mandarin Heritage (US)	English	Pure (Other First) / Mixed	1.07	0.18	0.72	1.59
Mandarin Heritage (US)	Mandarin	Pure (English First) / Pure (Other First)	1.20	0.23	0.77	1.89
Mandarin Heritage (US)	Mandarin	Pure (English First) / Mixed	1.25	0.18	0.90	1.45
Mandarin Heritage (US)	Mandarin	Pure (Other First) / Mixed	1.04	0.16	0.72	1.50
Spanish Heritage (US)	English	Pure (English First) / Pure (Other First)	1.37	0.37	0.72	2.60
Spanish Heritage (US)	English	Pure (English First) / Mixed	1.71 *	0.38	1.01	2.89
Spanish Heritage (US)	English	Pure (Other First) / Mixed	1.25	0.26	0.76	2.05
Spanish Heritage (US)	Spanish	Pure (English First) / Pure (Other First)	0.91	0.15	0.62	1.33
Spanish Heritage (US)	Spanish	Pure (English First) / Mixed	0.913	0.11	0.68	1.22
Spanish Heritage (US)	Spanish	Pure (Other First) / Mixed	1.01	0.12	0.75	1.35

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

APPENDIX D: Model comparisons of the Picture Naming Reaction Time (Mixed Language Block)

Model	Key Interaction	Compared with	AIC	Δ AIC	BIC	LRT X^2	df	LRT p value
M1	Main effects	---	54796.57	---	54852.35	---	9	---
M2	Group x Language	M1	54785.25	12	54853.42	15.32	11	< 0.001
M3	Language x Switch	M1	54798.53	2	54860.51	0.04	12	0.85
M2	Emotion x Switch	M1	54797.71	1	54859.69	0.86	10	0.36
M4	Group x Language x Switch	M4 lower-order	54790.19	9	54889.35	2.41	16	0.30
M5	Emotion x Switch x Group	M5 lower-order	54804.28	3	54903.45	0.87	16	0.65
M6	Emotion x Switch x Language	M6 lower-order	54800.37	1	54880.94	2.539	13	0.11
M7	Emotion x Switch x Emotion RT	M7 lower-order	54800.37	1	54880.94	2.740	13	0.10
M8	Language Moderation of M6	M8 without 4-way	54809.30	2	54933.25	0.07	20	0.80
M9	Group Moderation of M6	M9 without 4-way	54814.78	1	54982.12	3.13	27	0.21
M10	Fully interactive	M10 without 5-way	54824.71	3	55134.60	1.37	50	0.50

Note: LRT (likelihood-ratio tests); AIC (Akaike Information Criterion); BIC (Bayesian Information Criterion); df (degrees of freedom); Emotion RT refers to the standardized reaction time in the emotion word classification task. Main effects included in the baseline (M1) model are: Group, Language (English vs Other), Switch (Yes vs No), Emotion (negative vs positive), and Emotion RT. Lower-order models are used as a comparison to understand whether three-way comparisons are needed. Lower-order models include all main and two-way interactions within the three-way interaction except the three-way interaction itself.