Bilingualism: Language and Cognition

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Influence of language dominance on crosslinguistic and nonlinguistic interference resolution in bilinguals

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Research Article

Cite this article: Gálvez-McDonough, A.F., Blumenfeld, H.K., Barragán-Diaz, A., Robinson Anthony, J.J.D. and Riès, S.K. (2024). Influence of language dominance on crosslinguistic and nonlinguistic interference resolution in bilinguals. *Bilingualism: Language and Cognition*, 1–14
https://doi.org/10.1017/S1366728924000774

Received: 21 November 2023
Revised: 09 September 2024
Accepted: 11 September 2024

Keywords:
language dominance; crosslinguistic interference; false cognates; cognitive control; web-based experimental setting

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This article has earned badge for transparent research practices: Open Material Badge. For details see the Data Availability Statement.

This project was supported by an American Speech-Language Hearing Foundation New Century Scholars Award to SKR and an Institute on Deafness and Other Communication Disorders Award #F31DC019272 to JJDRA. The authors would like to thank the members of the Laboratory for the Brain Dynamics of Language and the Bilingualism and Cognition Lab at San Diego State University for their assistance with this project at its various stages, as well as all of the study participants.

Abstract

We examined how relative language dominance impacts Spanish–English bilinguals' crosslinguistic and nonlinguistic interference resolution abilities during a web-based Spanish picture-word interference naming task and a subsequent spatial Stroop paradigm, and the relationship between the two. Results show the expected interference and facilitation effects in the online setting across both tasks. Additionally, participants with greater English dominance had larger within-language, Spanish facilitation and marginally larger crosslinguistic (English to Spanish) interference effects reflected on accuracy performance. Similarly, participants with greater English dominance had larger nonlinguistic congruency facilitation effects. Our results are in line with other studies finding a relation between linguistic and nonlinguistic cognitive control. Correlated reaction time performance between the linguistic and nonlinguistic paradigms suggests that overcoming crosslinguistic interference may be partly based on cognitive control processes used outside of language. Modulations by language dominance underline the importance of accounting for relative language proficiency in bilinguals' two languages when studying bilingualism.

Highlights

- We studied how language dominance impacts interference resolution in bilinguals.
- We used web-based crosslinguistic and nonlinguistic interference tasks.
- Interference and facilitation effects were present across tasks.
- Greater English versus Spanish dominance was associated with larger effects.
- Language dominance modulates linguistic and nonlinguistic interference similarly.

1. Introduction

Of all of the human beings on the planet, people who speak two or more languages are considered to represent a majority over monolingual speakers (Grosjean, 2010). Bilingualism is in fact becoming the norm rather than the exception. However, the cognitive processes investigated in psycholinguistic research are still mostly studied within languages, with studies focusing on how these processes may differ in multilingual speakers still in the stark minority. This has important real-world implications because the clinical approaches that are derived from basic research do not benefit from as strong of a fundamental knowledge framework in the case of multilinguals. Continuing to develop the understanding of cognitive processes in and outside of language in bilinguals is therefore of critical importance. The present study focuses on word retrieval as it is one of the main functions which can break down in language disorders such as stroke-induced aphasia (Goodglass, 1993), neurodegenerative disorders and normal aging (Nicholas et al., 1985; Rohrer et al., 2008; Smith et al., 2018). Our study examines how word retrieval is influenced by crosslinguistic interactions and how these crosslinguistic interactions may be influenced by language dominance profiles. To further investigate the nature of these interactions, we compare them to analogous nonlinguistic interference and facilitation effects and how these may be differentially or similarly influenced by language dominance profiles.

A fundamental difference between multilinguals and monolinguals is that multilinguals' multiple languages are partially integrated and can influence one another during language processing (e.g., Blumenfeld et al., 2022; Costa et al., 2000; Kroll & Stewart, 1994). Previous studies have indeed provided evidence for nonselective (i.e., simultaneous) activation of bilinguals' two languages during language perception and production (Colomé, 2001; Costa et al., 1999; Starreveld et al., 2014). This simultaneous activation has been shown to lead to both facilitatory effects on language processing (Colomé, 2001; Kroll & Stewart, 1994; Pérez et al., 2010; Rosselli et al., 2014; Costa et al., 2000) as well as to crosslinguistic interference effects (e.g., von Studnitz & Green, 2002). In particular, cognate words, which are translation equivalents with similar form and semantic meaning, such as the Catalan-Spanish pair *gat-gato* (meaning "cat"), have been shown to elicit faster decision times in language perception tasks (e.g., Colomé, 2001) and faster naming times in language production tasks (e.g., Costa et al., 2000), as compared to noncognates, such as the Catalan-Spanish pair *taula-mesa* (meaning "table"). By contrast, *false* cognates, which are words that are crosslinguistically similar in form but semantically dissimilar in two languages, have the potential to create crosslinguistic interference (Mendoza et al., 2021; von Studnitz & Green, 2002; van Heuven et al., 2008; Vanlangendonck et al., 2020). For example, the English word *plum* is similar in form to the Spanish word *pluma* which means feather. In the current study, we focus on crosslinguistic interference triggered by false cognates.

False cognates have been shown to elicit more errors and longer processing times compared to noncognates. For example, in a visual lexical decision task, von Studnitz and Green (2002) instructed a group of German–English bilinguals to indicate through a button press if a presented letter string was a word in English or not. They found that when presented with a false cognate (also known as *interlingual homograph*), the bilingual participants were slower in their response than when presented with a noncognate (for similar findings, see Dijkstra et al., 1999; Lemhöfer & Dijkstra, 2004; van Heuven et al., 2008; Vanlangendonck et al., 2020). In a picture-word matching task, Mendoza et al. (2021) showed that Spanish–English bilinguals are slower at deciding whether a word and a presented picture match when the word is a false cognate of the picture name in the participant's other language. False cognates' influences on language production have, however, been less investigated compared to cognate effects. Interactive activation processes are thought to be at work during false cognate naming, where activation of shared phonologies across languages activates conflicting crosslinguistic lexical representations in a bottom-up manner, resulting in slowed naming (Costa et al., 2006; Kroll et al., 2006). Kroll et al. (2006), in discussion of initial findings on false cognate naming, likened the slowdown during naming to an "internally generated Stroop effect" (p. 126).

It has been posited that, in order to overcome interference effects caused by crosslinguistic interactions, bilinguals may actively inhibit the nontarget language during language use (e.g., Abutalebi & Green, 2007; Green, 1998). Even though the necessity for inhibition has been challenged (e.g., Blanco-Elorrieta & Caramazza, 2021), models of bilingual language processing still generally postulate the need for cognitive control mechanisms, especially in contexts where conflicting responses are activated across languages. It has also been theorized that these control mechanisms may be domain-general in nature (e.g., Kroll & Bialystok, 2013). This theory was proposed in light of findings showing that bilinguals can at times outperform monolinguals in nonlinguistic cognitive control tasks (e.g., Kroll & Bialystok, 2013). While evidence for a bilingual advantage in inhibitory control remains inconclusive across studies (see Lehtonen et al., 2018; van den Noort et al., 2019, for recent reviews), the interest in a possible link between bilinguals' ability to overcome crosslinguistic interference and domain general cognitive control mechanisms has remained. In particular, performance on cognitive control tasks involving inhibitory mechanisms has been shown to correlate with aspects of bilingualism, with possible modulations in the bilingualism-cognitive control link depending on the types of tasks, as well as age and language dominance profiles (e.g., Robinson Anthony & Blumenfeld, 2019; Freeman et al., 2022; Kroll et al., 2021; Luk et al., 2011; Xie & Pisano, 2019). For example, in Spanish–English bilinguals, Freeman et al. (2022) found that as proficiency in English (L2) increased, Stroop facilitation effects became smaller and Stroop interference effects increased. It was reasoned that as participants became more confident in the majority language, English, they would experience less conflict from Spanish during everyday English language use, reducing potential recruitment of control mechanisms for language processing and thus evincing larger Stroop interference effects. Findings from Robinson Anthony and Blumenfeld (2019), showing that unbalanced bilingualism is associated with smaller Stroop effects than balanced bilingualism, are consistent with this conclusion. In addition, Xie (2018) found that bilinguals with higher L2 proficiency had faster reaction times on a flanker arrows tasks, suggesting that increased L2 proficiency may also be associated with greater cognitive efficiency. Findings of this nature are consistent with the adaptive control hypothesis (Green & Abutalebi, 2013), which posits that the language context, and the conflict experienced on a daily basis between bilinguals' two languages, modulates the nonlinguistic cognitive control system.

As performance on both nonlinguistic cognitive control tasks and tasks that capture crosslinguistic interaction has been shown to be modulated by language proficiency in bilinguals, an important consideration in studies of bilingualism is how we describe linguistic profiles of bilingual populations. Indeed, there is tremendous variability across bilinguals in aspects of language use and history, such as extent of exposure to the language, contexts and duration of immersion. In studies of language and cognition in bilinguals, definitions of language dominance have varied between studies and differ in the degree to which they predict linguistic and nonlinguistic performance (e.g., Robinson Anthony & Blumenfeld, 2019; Bedore et al., 2012; Sheng et al., 2014). For example, Robinson Anthony and Blumenfeld (2019) examined multiple indices of language dominance and their relation to performance on linguistic and nonlinguistic tasks in young Spanish–English bilingual adults. These measures of language dominance included self-reported proficiency, self-reported exposure, expressive language knowledge, receptive language knowledge and a *hybrid* index composed of all these subjective and objective measures. The main findings revealed that a continuous *hybrid* index of language dominance significantly predicted *both* crosslinguistic cognate effects in English and Spanish as well as inhibitory control skills. In that study, cognate effects were indexed through a receptive vocabulary task that included cognate and noncognate words, while inhibitory control skills were indexed through a nonlinguistic spatial Stroop task. Critically, unbalanced bilingualism (e.g., lower proficiency in Spanish than English) was associated with smaller Stroop effects and larger crosslinguistic cognate effects during Spanish word identification. Similar findings on language dominance and crosslinguistic cognate effects were reported in naming tasks by Pérez et al. (2010) in children, and Rosselli et al. (2014) in adults. Prior studies had also linked inhibitory control to language dominance, but various results were reported. Better inhibitory control skills have been reported to be associated with more balanced bilingualism in children (Prior et al., 2016; Thomas-Sunesson et al., 2018), but with more unbalanced bilingualism in older adults (Goral et al., 2015; for null findings on a link between language dominance and inhibitory control, see Rosselli et al., 2016; Yow & Li, 2015). Overall, studies that examine individual participant characteristics such as language dominance together with crosslinguistic interaction and inhibitory control skills can provide a window into how language interaction may be tied to cognitive control. We take this approach in the *current study* to help elucidate how crosslinguistic interaction and cognitive control may be linked during word production across the language dominance continuum.

The nonlinguistic control neurobiological network has been shown to at least partially overlap with that of linguistic control (Green & Abutalebi, 2013). For example, Mendoza et al. (2021) performed a scalp EEG study on Spanish–English bilinguals as they performed an English picture-word matching task, which contrasted congruent, unrelated, and false cognate trials, as well as the arrow version of the Eriksen flanker task (i.e., participants were instructed to indicate the direction of a central arrow while ignoring the flanking arrows). Behavioral results revealed linguistic and nonlinguistic interference effects in both tasks, but these effects were not significantly correlated across participants. However, EEG results revealed a similar medial frontal component in the nonlinguistic and linguistic tasks. Importantly, this medial frontal component had already been reported in nonlinguistic cognitive control tasks and has been associated with decision making (Carbonnell et al., 2013; Vidal et al., 2003, 2011). Results also revealed a left prefrontal component peaking around 200 ms before electromyographic onset that was sensitive to congruency in the linguistic task but was absent in the nonlinguistic task. These results suggest a partial overlap between linguistic and nonlinguistic cognitive control and decision-making processes. Due to this partial overlap, the two should be studied in tandem to further understand their mutual influence on one another. In the present study, we examine the relationship between false cognate processing and inhibitory control across a larger participant set and in consideration of language dominance.

1.1. Current study

In the present study, we examine how Spanish–English bilinguals retrieve words depending on language dominance and the presence of crosslinguistic interference during a Spanish naming task. We examine the relationship between linguistic and nonlinguistic abilities by comparing bilinguals' performance on a picture-word interference (PWI) paradigm (Costa et al., 1999; Costa & Caramazza, 1999) and a nonlinguistic spatial Stroop paradigm (Blumenfeld & Marian, 2011; Giezen et al., 2015; Liu et al., 2004). In the PWI task, participants named the presented image in Spanish while ignoring a superimposed distractor word. This distractor word was written in Spanish and was either a false cognate with the picture target's English translation, unrelated, or identical to the picture name. In the nonlinguistic spatial Stroop task, participants indicated the direction of an arrow through a button press while ignoring its position on the screen. We have previously argued that the nonlinguistic Stroop task (where participants must ignore one irrelevant perceptual dimension of a stimulus, arrow location) can be aligned with tasks that elicit crosslinguistic competition, requiring bilinguals to ignore the perceptual dimension of the stimulus that corresponds to the nontarget language (e.g., Blumenfeld & Marian, 2014; Freeman et al., 2017; Mendoza et al., 2021). Across a number of studies, this link has yielded significant correlations across bilingual language and nonlinguistic Stroop performance (e.g., Blumenfeld & Marian, 2013; Freeman et al., 2017; Giezen & Emmorey, 2016; Mercier et al., 2014; Robinson Anthony & Blumenfeld, 2019). As outlined above, in the examination of different language dominance measures and their ability to capture cognate effects and inhibitory control skills, Robinson Anthony and Blumenfeld (2019) found that a continuous hybrid measure of language dominance includes enough nuance to capture crosslinguistic interaction and Stroop-type inhibition performance across language dominance profiles. Here, we implement a similar hybrid description of language dominance with which we aim to effectively account for performance in our sample population across the bilingualism spectrum. Importantly, in our study, we combine language proficiency measures from both subjective (self-reported) language production, comprehension and reading skills as well as current exposure to each language, and objective picture-naming abilities in order to calculate our hybrid language dominance measure. This hybrid measure is therefore more comprehensive than each measure taken independently and is expected to be a good predictor of performance on our experimental tasks as in Robinson Anthony and Blumenfeld (2019).

Like many other researchers, we shifted to online data collection as the start of the COVID-19 pandemic prevented in-person testing. Up until the start of the pandemic, language production experiments had scarcely been conducted online. While online data collection for auditory processing had already been established (Dufau et al., 2011; Ernestus & Cutler, 2015; Keuleers et al., 2010), many researchers assumed that internet-based testing of speech production would pose serious challenges. However, recent studies have shown that accurate and reliable data can be collected via internet-based speech production experiments (Fairs & Strijkers, 2021; Vogt et al., 2022).

The purpose of the present study was threefold. First, we assessed whether the expected interaction between crosslinguistic effects and language dominance during word retrieval could be effectively captured in an online production experiment. We predicted that the more English dominant a participant was, the greater the crosslinguistic interference effect would be during the Spanish PWI task (based on findings from cognate studies, Pérez et al., 2010; Robinson Anthony & Blumenfeld, 2019; Rosselli et al., 2014). Furthermore, we anticipated that the more Spanish dominant a participant was, the less likely they would rely on within-language identity facilitation during the Spanish task. Second, we examined if the nonlinguistic interference effect would also be similarly modulated by language dominance. We predicted that participants who are more dominant in English would show larger Stroop effects as they are less likely to experience crosslinguistic interference on a regular basis compared to individuals who are more dominant in Spanish and need to resolve interference more often during immersion in the English-majority language. Based on Freeman et al. (2022), it was also expected that as proficiency in English increased, the Stroop facilitation effects would become smaller. Third, we examined the relationship between inhibitory control abilities in the linguistic and nonlinguistic modalities. While Mendoza et al. (2021) did not find such a correlation of the behavioral interference effects, the overlap found in EEG components suggests partly overlapping resources between linguistic and nonlinguistic cognitive control processes. Because we tested a larger participant sample in the current study, we expected to observe a significant correlation between crosslinguistic and nonlinguistic behavioral interference effects in light of the Mendoza et al.'s findings.

2. Methods

2.1. Participants

Fifty-nine Spanish–English bilinguals between the ages of 18 and 54 years were recruited from the San Diego State University student

https://doi.org/10.1017/S1366728924000774 Published online by Cambridge University Press

Table 1. Language experience and proficiency questionnaire

N = 52	Mean (SD)	Range
Age	23.9 (6.3)	18–54
Years of education	16.65 (2.9)	12–27
Age of acquisition – Spanish	2.42 (3.9)	0–15
Age of acquisition – English	5.14 (3.1)	0–13
Age of fluency – Spanish	5.45 (5.18)	0–21
Age of fluency – English	7.71 (3.97)	3–20
Years of family exposure – Spanish	17.77 (9.97)	0–39
Years of family exposure – English	15.11 (12.07)	0–51
Years of school exposure – Spanish	5.6 (6.17)	0–21
Years of school exposure – English	15.18 (5.91)	0–26
Self-reported proficiency in Spanish	8.7 (1.1)	6.3–10
Self-reported proficiency in English	9.5 (.81)	6–10
Self-reported exposure to Spanish (%)	39.23 (20.6)	40–100
Self-reported exposure to English (%)	59.56 (20.6)	0–95

population as well as from the public. Seven participants were excluded from the analyses due to incomplete data sets or error rates higher than the mean error rate over participants plus two standard deviations in either the linguistic or nonlinguistic task, resulting in a final dataset of 52 participants (mean age = 23.9 years, SD = 6.3 years). This study was approved by the Institutional Review Board of San Diego State University. All participants provided informed consent and received either class credit or monetary compensation in exchange for their participation. The criteria used to determine eligibility for this study are as follows: (a) must have conversational proficiency levels in both English and Spanish as measured by a proficiency score of four or higher in both languages across the 10-point *Language Experience and Proficiency Questionnaire* (LEAP-Q, Marian et al., 2007) scales in each language, (b) must not have any current or past known history of psychiatric or neurological disorders, (c) must not have a history of alcohol or drug abuse, (d) must have reported no known language or learning disabilities on the LEAP-Q and (e) must have reported normal or corrected-to-normal vision and hearing. See Table 1 for participants' current ages, years of education and ages of language acquisition, as well as self-reported proficiencies and current exposures to English and Spanish as reported through the LEAP-Q.

In addition to English and Spanish, 13 participants reported proficiency in other languages, including French, Portuguese, Italian, Russian, Japanese, American Sign Language, Korean, German and Turkish. For 12 of these participants, one of these was their third language or beyond. One participant reported English as their first acquired language, one of these other languages as their second acquired language and Spanish as their third acquired language. Across our dataset, self-reported current exposure did not exceed 11% for any language outside of Spanish or English. Given the high prevalence of multilingualism in the linguistic community we recruited from, we kept these self-reported multilinguals in the sample to reflect the reality of Spanish–English interaction in the context of some other language knowledge.

Because the current research goal was to examine crosslinguistic and nonlinguistic processing across language dominance profiles, variability in participants' language dominance was sought out, as indexed by a wide range of self-reported proficiencies in both Spanish and English (i.e., 4–10 on the LEAP-Q). Statistical differences between Spanish and English indicated earlier ages of acquisition for Spanish (t (51) = −3.58, $p < .001$), greater self-reported proficiencies in English (t (51) = −3.82, $p < .001$) and greater self-reported current exposures in English (t (51) = −3.59, $p < .001$). These characteristics of the sample are indicative of a primarily heritage Spanish-speaking sample population.

2.2. Materials and design

All participants completed web-based versions of an abbreviated version of the LEAP-Q (Marian et al., 2007), the Multilingual Naming Test (MINT, Gollan et al., 2012) adapted for online administration, and the two experimental tasks: a PWI task (similar to Mendoza et al., 2021) and a nonlinguistic Stroop task (Giezen et al., 2015).

2.2.1. Language proficiency assessments

The LEAP-Q (Marian et al., 2007) is a questionnaire used to assess the linguistic profiles of adult multilingual populations. An abbreviated version of the LEAP-Q was administered to collect demographic information as well as participants' self-reported language experience (including age of acquisition, age of fluency, current exposure and learning history for each language) and proficiency (including speaking, understanding and reading for each language). The LEAP-Q has been validated to be independently completed by participants, making it suitable to the web-based data collection format.

The MINT (Gollan et al., 2012) is a picture-naming task designed to measure expressive language abilities. The test has been validated in multiple languages, including Spanish and English, and does not include crosslinguistically overlapping targets (i.e., cognates or false cognates). In this task, participants were presented with 68 black-and-white line drawings that increased in relative naming difficulty with each trial. The full test was administered twice, once in Spanish and once in English, in order to objectively assess the participants' expressive language abilities in each language. It is important to note that since an online version of the task was used, participants were not provided with the semantic and phonetic cues that are typically provided when they cannot accurately find the name of the picture. Furthermore, instead of following the usual 'ceiling' rule where the test is discontinued after participants make six incorrect responses, participants were administered all items of the test.

2.2.2. PWI task

Stimuli developed for the current study consisted of 42 photographs of common objects selected through Google image searches. Only photographs with creative common licenses were selected and Photoshop was used to remove backgrounds from images as needed. All stimuli were 240 × 240 pixels large, occupied 30% of the screen in height, were centered against a white, square background and superimposed with a Spanish distractor word that was written in an all-capital black Arial font over the center of the image.

Critical stimuli were repeated across three conditions: a false cognate (FC) condition, in which the distractor word was a false cognate with similar phonological form but different meaning to the English picture name (false cognates underlined, i.e., target picture name – aceite = English "oil"; distractor word – OLA = English "wave"); an unrelated condition, where the distractor word and image were UR in both form and meaning (i.e., target picture name

https://doi.org/10.1017/S1366728924000774 Published online by Cambridge University Press

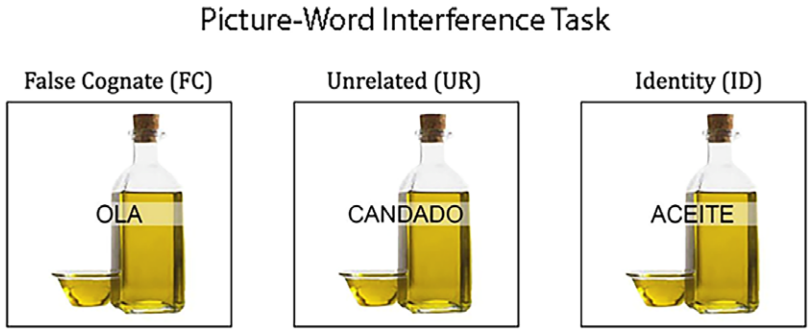

Figure 1. Example stimuli for the picture-word interference task in the false cognate (FC) condition (the stimulus image and superimposed distractor word do not match and the distractor word is a false cognate to the English picture name; OLA = English "wave"), the unrelated (UR) condition (the stimulus image and superimposed distractor word do not match and are unrelated in form and meaning; CANDADO = English "lock") and the identity (ID) condition (the stimulus image and superimposed distractor word match; ACEITE = English "oil").

– aceite; distractor word – CANDADO = English "lock"); or an identity (ID) condition, where the distractor word and image matched in the target language, Spanish (i.e., target picture name – aceite; distractor word – ACEITE) (see Figure 1). All of the superimposed distractor words were represented as images in other trials, meaning that the distractor words were a part of the response set, making them more likely to cause interference, as shown in a semantic version of the PWI paradigm (Piai et al., 2012).

This task consisted of 210 trials (42 false cognate, 84 UR and 84 identity trials) that were split into four blocks (see Table A1 in Appendix A for a breakdown of stimuli by condition). The selected stimuli varied in semantic categories, word length and lexical frequency as derived from the SUBTLEX database (Cuetos et al., 2012; see Table A2). Importantly, all items appeared in all conditions which meant that all measures were counterbalanced within participant[1]. We measured the phonological overlap between false cognate pairs (e.g., "ola" and "oil") and UR pairs (e.g., "aceite" and "candado") using the Cross-Linguistic Overlap Scale for Phonology (COSP, Kohnert, 2004). As intended, the COSP scores were significantly higher for false cognates than for UR pairs in our stimuli (t (20) = −10.97, p < .001; mean COSP score for FC pairs: 6, SD: 1.52; mean COSP score for UR pairs: 1.81, SD: .93).

2.2.3. Nonlinguistic spatial Stroop task

The nonlinguistic spatial Stroop task is a test utilized to measure how efficiently participants resolve conflict between stimulus dimensions, with more efficient performance related to better inhibitory control skills. The current version of the task was based on a task version developed by Giezen et al. (2015). Stimuli consisted of light gray arrows that varied in both direction and position, were 164 × 152 pixels large and occupied 20% of the height of a black screen. The stimuli could be presented across one of three conditions: an incongruent condition, in which the direction of the arrow and its position on a screen did not align (i.e., a left-facing arrow presented on the right side of the screen); a neutral condition, in which a left- or right-facing arrow was presented at the center of a screen and a congruent condition, in which the direction of the arrow and its position on a screen aligned (i.e., a left-facing arrow presented on the left side of a screen). For evidence that a measure like the nonlinguistic spatial Stroop task can be successfully administered in a web-based context, see Gosselin and Sabourin (2023).

Stimuli were presented across four blocks consisting of a total 210 trials (126 congruent, 42 incongruent and 42 neutral trials), each containing an equal number of left- and right-pointing arrows. These trials were preceded by a familiarization block of 20 trials (12 congruent, 4 incongruent and 4 neutral).

2.3. Procedure

Individuals interested in participating received a link and instructions on how to complete the online study, which was run through Labvanced (Finger et al., 2017), an online experiment web-builder and experiment administration platform that participants could independently access to complete the study. After completing the consent form, participants filled out a series of questions to determine if they met the inclusion criteria followed by the LEAP-Q, both of which were used to screen for participation eligibility (see Section 2.1.). Participants then completed the MINT in Spanish.

Participants then completed a familiarization phase for the PWI task where they were presented with each of the 42 photographs to make sure they used the intended labels during naming on the PWI task. Participants were presented with each photograph for 2000 ms and asked to name the image as quickly and as accurately as possible. At the end of the 2000 ms, the target response appeared written below the image for 1000 ms. Following this familiarization phase, the participants began the PWI task. In each trial, participants first saw a fixation cross, followed by the stimulus for 2000 ms and a break screen for 1000 ms. Audio recordings were captured during both the stimulus presentation and the subsequent break screen for a total of 3000 ms for each trial starting with stimulus onset. Participants were instructed to provide a one-word response where they named the image in Spanish as quickly and as accurately as possible, while ignoring the superimposed distractor word. Participants were asked to name picture targets without their respective articles (e.g., *ciruela*, not *la ciruela*) to reduce variability in the naming latency measurements.

Following the PWI task, participants completed the practice trials for the nonlinguistic spatial Stroop task, followed by the experimental trials. They were instructed to press keys on their keyboard according to the direction in which the arrow was pointing ('J' for right and 'F' for left) as quickly and as accurately as possible, while ignoring the arrow's position on the screen. Participants first viewed a fixation cross, followed by a 1200 ms

[1]Word length ranged from one to four syllables and lexical frequency of the stimulus set ranged from .17 to 137.98 words per million (mean: 21.04 words per million) as listed in the SUBTLEX-ESP database (Cuetos, Gonzalez-Nosti, Barbon & Brysbaert, 2012).

https://doi.org/10.1017/S1366728924000774 Published online by Cambridge University Press

window where the stimulus was presented and a 500 ms window where a break screen was presented. Responses could be made during the 1700 ms composed of the stimulus and break screen presentation. Finally, participants completed the MINT task again, but in English.

The order of first the Spanish then the English MINT was strategically chosen across all participants so that participants would complete a Spanish naming task prior to starting the Spanish experimental PWI and to allow maximum time between the Spanish and English versions of the task. Completion of a Spanish task (the MINT) prior to the Spanish experimental PWI ensured that participants would have entered a Spanish language mode (Grosjean, 1998) prior to starting the experimental task, with their Spanish language activated. This strategy would ensure that performance would more closely reflect the Spanish knowledge of participants given that English was the dominant language of the environment. Furthermore, inserting the nonlinguistic Stroop task between the Spanish PWI and English MINT allowed us to avoid an abrupt switch from a Spanish to an English lexical retrieval task. This was done because extended naming in one language has been shown to temporarily inhibit lexical retrieval in the other language (e.g., Lee & Williams, 2001; Levy et al., 2007). Instead, completion of the nonlinguistic task between the two language blocks allowed for a more gradual switch from Spanish back to English.

3. Data coding and analyses

3.1. Language dominance profiles

Language dominance was established by creating an averaged composite score of subjective and objective measures of Spanish and English proficiencies, including self-reported proficiency in speaking, understanding and reading Spanish and English, self-reported current exposure to Spanish and English and objective performance accuracy scores for each language as in Robinson Anthony and Blumenfeld (2019). The MINT score was used as the objective language proficiency measure. Including self-reported proficiencies as well as current exposure to each language has been shown to increase the predictive power of objectively derived language dominance (Robinson Anthony & Blumenfeld, 2019). Using MINT scores as the objective proficiency measure is expected to be most closely related to performance in our linguistic picture-naming task. Specifically, Spanish and English responses and scores were converted into proportion correct or proportion of the total reported (ranging from 0 to 1) for each language proficiency measure. Then, difference scores were calculated for each of the language proficiency measures by subtracting the English proportion from the Spanish proportion. Finally, these difference scores were averaged across all measures to index language dominance for each participant. In doing so, a language dominance continuum was established across participants, where the more positive scores indicate greater Spanish dominance, while the more negative scores indicate greater English dominance. Those with scores closer to 0 are considered more balanced bilinguals (see Table 2 for an example of a language dominance index calculation).

Table 2. Language dominance calculation

	Spanish	English	Difference score
Proficiency	(0.8, 1.0, 0.9) = 0.9	(1.0, 1.0, 1.0) = 1.0	−0.1
Exposure	0.5	0.5	0.0
MINT accuracy	0.71	0.91	−0.2
Language Dominance Index			−0.1

Note: Self-reported proficiency is an average score consisting of speaking, understanding and reading proficiencies. Self-reported proficiency is reported by participants on a scale from 0 to 10. Self-reported current exposure considers all languages so that they total 100% exposure. MINT accuracy is reported as the proportion of items correctly named.

3.2. PWI task

Trials were coded as errors when participants did not produce a response or produced a nontarget verbal response (i.e., producing the distractor word instead of the image name, naming the image in English, or producing a word phonetically different from the target in turn yielding a word with a different semantic meaning, e.g., target picture name – pluma; response – puma). Trials with nontarget responses were considered correct if they were a synonym of the target response and were consistently used to name a stimulus image (i.e., pizarron instead of target pizarra or elote instead of target maíz). Reaction times for each trial were measured as the difference between the time of stimulus presentation and the time of vocal onset, as coded through CheckVocal (Protopapas, 2007). Trials containing hesitations were excluded from the reaction time analysis.

3.3. Nonlinguistic spatial Stroop task

For the nonlinguistic spatial Stroop task, trials were coded as errors when the incorrect key was pressed or when no response was provided. Reaction times were measured as the difference between the time of stimulus presentation and the time of a key press for each trial.

3.4. Statistical analyses

Statistical analyses were performed through RStudio version 4.2.2 (R Core Team, 2022). The lme4 package was used to compute linear and generalized mixed-effect models for reaction times and accuracy rates, respectively (Baayen et al., 2008; Jaeger, 2008). We tested for effects of Condition and Language Dominance while controlling for random effects of item and participant and random slopes for condition within item and participant. While Condition was a categorical variable in all analyses (false cognate, UR and identity trials on the PWI task; incongruent, neutral and congruent trials on the Stroop task), Language Dominance was entered into the models as a continuous variable. The p values were obtained using type-III analyses of deviance tables, providing Wald chi-square (Wald χ^2) tests and associated p values for the fixed effects in the generalized linear mixed-effects models, using the R package car (Fox & Weisberg, 2018). For all models, we report Wald χ^2 values and p values from the analysis of deviance tables, as well as raw beta estimates, standard errors, z values for accuracy rates and t values for reaction times from the mixed-effect models.

Crosslinguistic interference effects were calculated by comparing the false cognate and UR conditions in the PWI task, while nonlinguistic interference effects were calculated by comparing the incongruent and neutral conditions in the Stroop task. Within-language identity facilitation effects were calculated by comparing the UR and identity conditions in the PWI task and nonlinguistic facilitation effects were calculated by comparing the neutral and congruent conditions in the Stroop task. Data from participants with error rates greater than two standard deviations above the

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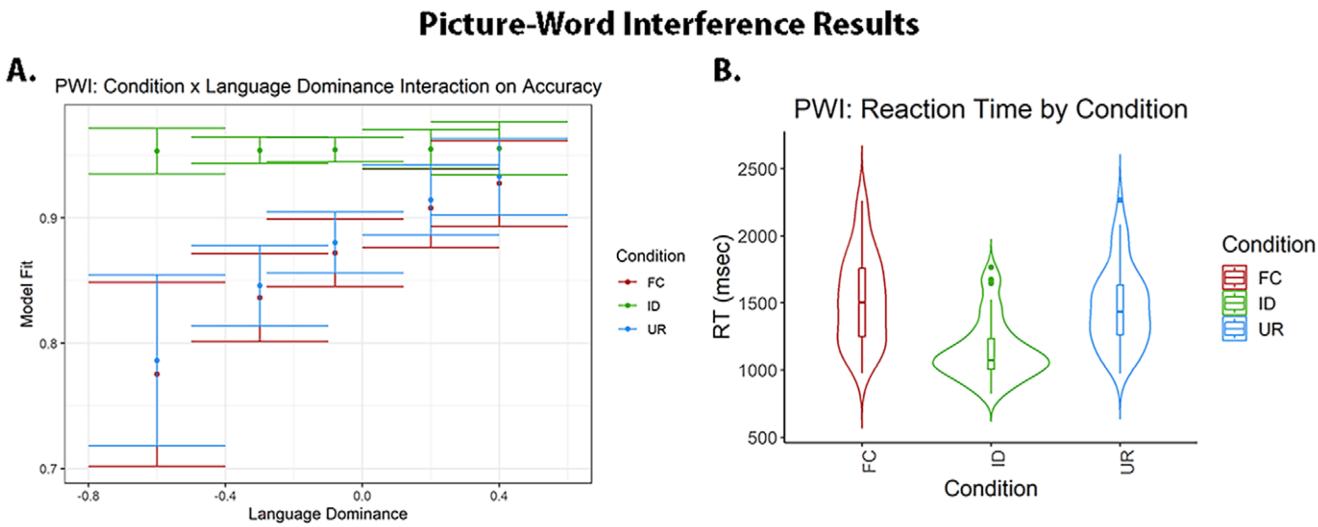

Figure 2. (A) Model fit by Condition and Language Dominance in the PWI task on accuracy. Accuracy was the highest in the ID condition and lowest in the FC condition. The size of the difference between FC and UR and ID and UR changed with Language Dominance. More positive scores are associated with higher Spanish over English language dominance, while more negative scores are associated with higher English over Spanish language dominance as calculated through our language dominance ratio. Error bars reflect standard errors. (B) Violin plot of the reaction time distributions by Condition in the PWI task. The horizontal lines indicate the median reaction times per condition, the boxes indicate the interquartile ranges per condition and the whiskers indicate the data range. Significant differences were present between FC and UR conditions as well as between ID and UR conditions.

mean error rate across participants in either task was excluded from the analyses.

Finally, we investigated the possible relationship in performance between the PWI and Stroop tasks, as well as Language Dominance. To investigate a possible link between interference effects in the two tasks, we computed linear regression models between the raw beta values for the FC versus UR comparison in the PWI task, raw beta values for the incongruent versus neutral comparison in the Stroop task and the Language Dominance Index. Similarly, to investigate a possible link between facilitation effects in the two tasks, we ran linear regressions between the raw beta values for the ID versus UR comparison in the PWI task, raw beta values for the congruent versus neutral comparison in the Stroop task and the Language Dominance Index.

4. Results

4.1. PWI task

There was a significant effect of Condition on Accuracy (Wald $\chi^2(2) = 37.69$, $p < .001$). Accuracy was lower in the FC than in the UR condition ($\beta_{raw} = -.37$, $SE = .10$, $z = -3.85$, $p < .001$) and higher in the ID than in the UR condition ($\beta_{raw} = .66$, $SE = .11$, $z = 6.10$, $p < .001$). There was no main effect of Language Dominance on Accuracy (Wald $\chi^2(1) = 1.44$, $p = .231$). However, there was a significant interaction between Condition and Language Dominance (Wald $\chi^2(2) = 7.19$, $p = .027$). This interaction is caused by a marginal interaction between the crosslinguistic interference effect and Language Dominance ($\beta_{raw} = .42$, $SE = .25$, $z = 1.65$, $p = .099$) and a significant interaction between the identity facilitation effect and Language Dominance ($\beta_{raw} = -.85$, $SE = .33$, $z = -2.60$, $p = .009$). Both the crosslinguistic interference and identity priming effects tended to get smaller with increasing Spanish over English language dominance (see Figure 2A).

There was also a main effect of Condition on Reaction Times (Wald $\chi^2(2) = 116.18$, $p < .001$). Reaction times were longer in the FC than in the UR condition ($\beta_{raw} = -5.33 \times 10^{-5}$, $SE = 7.99 \times 10^{-6}$, $z = -6.67$) and shorter in the ID than in the UR condition ($\beta_{raw} = 1.03 \times 10^{-4}$, $SE = 9.60 \times 10^{-6}$, $z = 10.69$) (see Figure 2B). There was no main effect of Language Dominance (Wald $\chi^2(1) = 1.39$, $p = .238$) and no interaction between Condition and Language Dominance on reaction times (Wald $\chi^2(2) = 3.13$, $p = .209$).

4.2. Nonlinguistic spatial Stroop task

There was a significant effect of Condition on Accuracy (Wald $\chi^2(2) = 110.78$, $p < .001$). Accuracy was lower in the incongruent than neutral condition ($\beta_{raw} = -1.27$, $SE = .13$, $z = -9.65$, $p < .001$) and higher in the congruent than neutral condition ($\beta_{raw} = .90$, $SE = .12$, $z = -7.36$, $p < .001$). There was no main effect of Language Dominance (Wald $\chi^2(1) = .01$, $p = .925$), but there was a marginal interaction between Condition and Language Dominance (Wald $\chi^2(2) = 4.72$, $p = .095$). This was caused by an interaction between the congruency facilitation effect (between the congruent and neutral conditions) and Language Dominance ($\beta_{raw} = -.758$, $SE = .36$, $z = -2.09$, $p = .037$), where the congruency facilitation effect was smaller with increasing Spanish over English language dominance (see Figure 3A). There was no significant interaction between the interference effect and Language Dominance ($\beta_{raw} = .68$, $SE = .44$, $z = 1.55$, $p = .122$).

There was also a main effect of Condition on Reaction Times (Wald $\chi^2(2) = 126.54$, $p < .001$). Reaction times were longer in the incongruent than in the neutral condition ($\beta_{raw} = -1.88 \times 10^{-4}$, $SE = 2.36 \times 10^{-4}$, $t = -.797$) and shorter in the congruent than in the neutral condition ($\beta_{raw} = 1.87 \times 10^{-4}$, $SE = 2.36 \times 10^{-4}$, $t = .791$). There was no main effect of Language Dominance (Wald $\chi^2(1) = 1.84$, $p = .175$) and no interaction between Condition and Language Dominance (Wald $\chi^2(2) = .41$, $p = .815$) (see Figure 3B).[2]

[2]We also ran the analyses replacing our language dominance index with its absolute value to see if how balanced individuals were was a better predictor of performance in the nonlinguistic task. For comparison, we also reran the analyses in the linguistic task. We found no main effect of Absolute Language Dominance in the nonlinguistic task on Accuracy (Wald $\chi2(1) = .008$, $p = .931$) or

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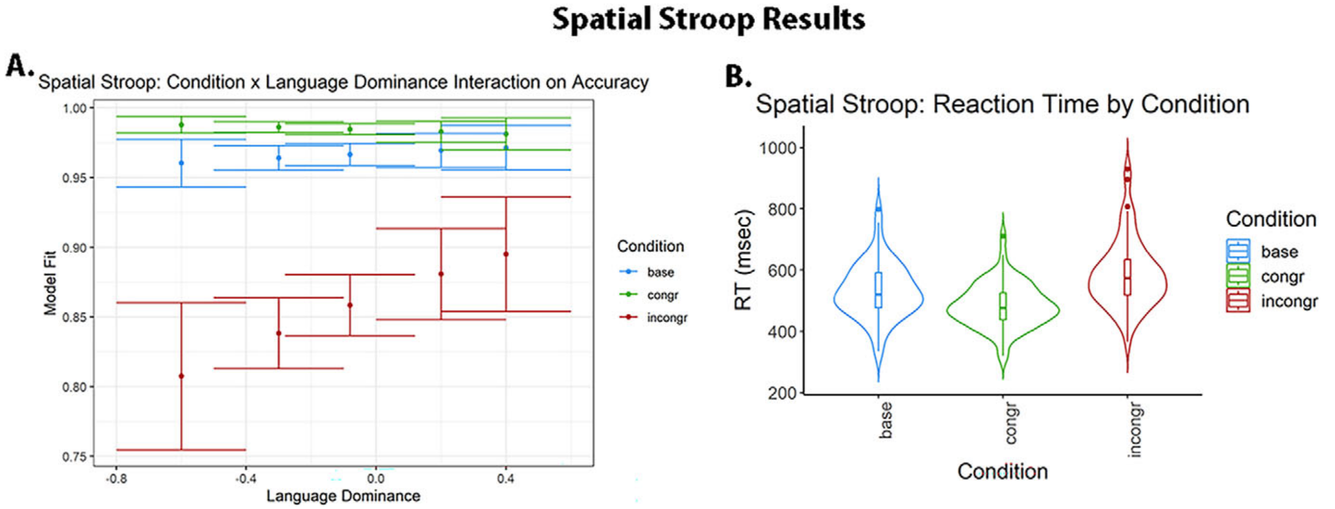

Figure 3. (A) Model fit by Condition and Language Dominance in the spatial Stroop task on accuracy. Accuracy was the highest in the congruent condition (congr) and lowest in the incongruent condition (incongr), with the baseline condition (base) in the middle. The size of the difference between the congruent and baseline conditions changed with Language Dominance. More positive scores are associated with higher Spanish over English language dominance, while more negative scores are associated with higher English over Spanish language dominance as calculated through our language dominance ratio. (B) Violin plot of the reaction times distributions by Condition in the spatial Stroop task. The horizontal lines indicate the median reaction times per condition, the boxes indicate the interquartile ranges per condition and the whiskers indicate the data range. Significant differences emerged between baseline (base) and congruent (congr) conditions as well as between baseline and incongruent (incongr) conditions.

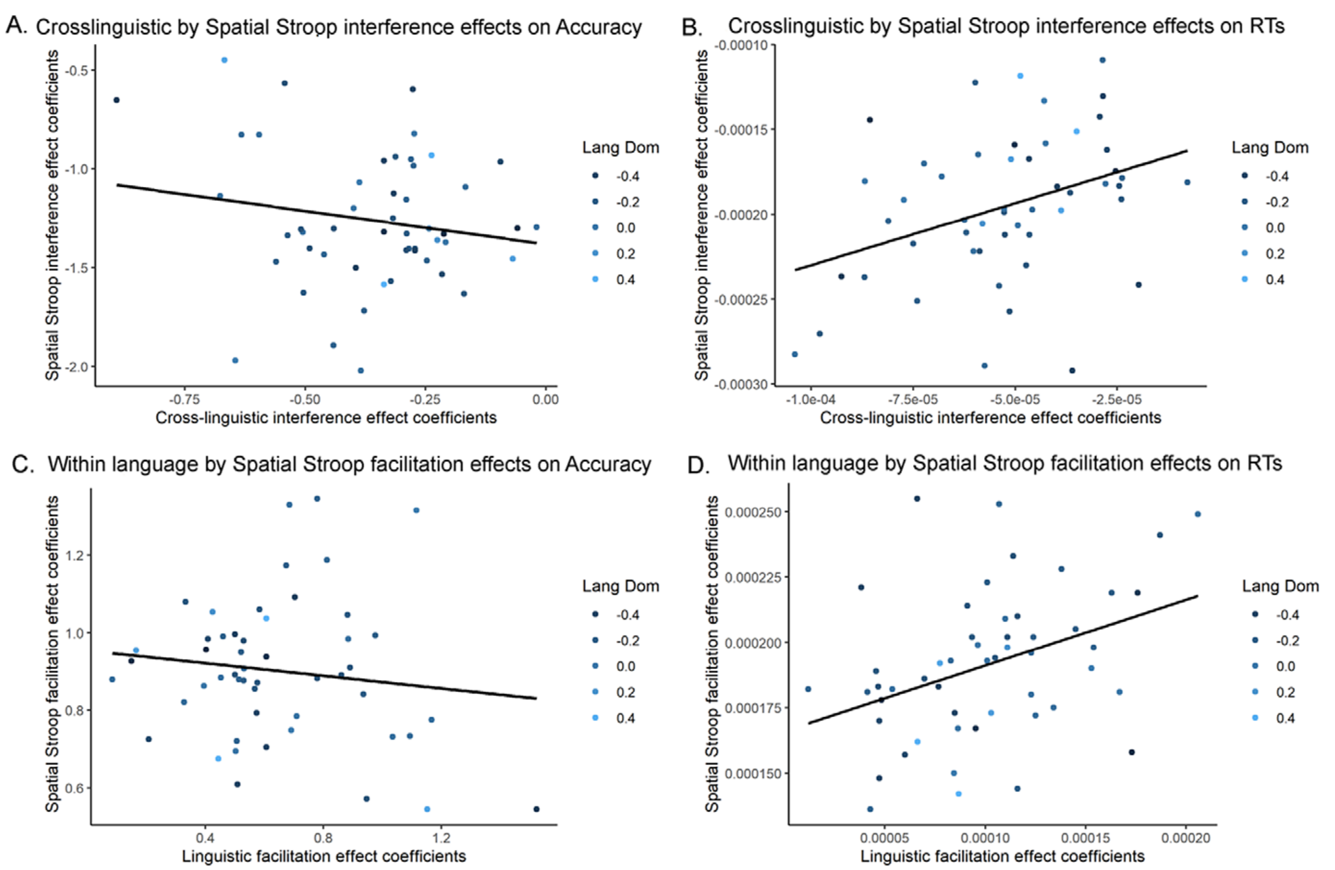

Figure 4. Scatterplots showing the relationships between linguistic and nonlinguistic interference (plots A and B), and facilitation effects (plots C and D) on accuracy (plots A and C) and reaction times (plots B and D). Language dominance scores are color coded in shades of blue, with darker colors associated with more English-dominant scores and lighter colors associated with more Spanish-dominant scores.

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4.3. Relation between interference and facilitation on the PWI and nonlinguistic Stroop task

There was no relationship between the crosslinguistic and nonlinguistic interference effects found on accuracy rates (β_{raw} = −.080, *SE* = .081, *t* = −.981, *p* = .332), no modulation by Language Dominance (β_{raw} = .096, *SE* = .306, *t* = .315, *p* = .755) and no main effect of Language Dominance (β_{raw} = .082, *SE* = .379, *t* = .215, *p* = .831) (see Figure 4 A; note that we excluded the results of one participant for the linear regressions on accuracy and reaction times as this participant had a negative spatial Stroop facilitation effect coefficient and was an outlier).

However, we did find a positive relationship between the crosslinguistic and nonlinguistic interference effects found on reaction times (β_{raw} = .272, *SE* = .093, *t* = 2.92, *p* = .005): when the linguistic interference effect increased, the nonlinguistic interference increased as well. This relationship was not modulated by Language Dominance (β_{raw} = .392, *SE* = .333, *t* = 1.18, *p* = .245), and there was no main effect of Language Dominance (β_{raw} = .560 × 10^{-4}, *SE* = .586 × 10^{-4}, *t* = .96, *p* = .344; see Figure 4B).

Similarly, there was no relationship between the linguistic and nonlinguistic facilitation effects found on accuracy rates (β_{raw} = −.109, *SE* = .250, *t* = −.44, *p* = .665), no modulation by Language Dominance (β_{raw} = .810, *SE* = .984, *t* = .82, *p* = .414), and no main effect of Language Dominance (β_{raw} = −.638, *SE* = .861, *t* = −.74, *p* = .463; see Figure 4C).

However, there was a positive relationship between the linguistic and nonlinguistic facilitation effects found on reaction times (β_{raw} = .858, *SE* = .280, *t* = 3.07, *p* = .004): when the linguistic facilitation effect increased, the nonlinguistic facilitation effect increased as well. This relationship was not modulated by Language Dominance (β_{raw} = 1.30, *SE* = 1.00, *t* = 1.29, *p* = .205), and there was no main effect of Language Dominance (β_{raw} = −2.05 × 10^{-4}, *SE* = 1.78 × 10^{-4}, *t* = −1.15, *p* = .255; see Figure 4D).

5. Discussion

The purpose of the present study was threefold. First, we assessed whether the expected crosslinguistic interference effects and within-language identity facilitation effects would be modulated by language dominance and if this could be effectively captured in an online production experiment. Second, we examined if nonlinguistic interference effects would also be modulated by language dominance, a finding that would suggest an influence of linguistic experience on nonlinguistic processes. Third, we examined the relationship between inhibitory control abilities and facilitation effects in the linguistic and nonlinguistic modalities. Analyses revealed that crosslinguistic interactions with language dominance can be effectively assessed during word retrieval in an online modality. In particular, within-language facilitation significantly interacted with language dominance: the more participants' English proficiency over their Spanish proficiency increased, the significantly larger the within-language Spanish identity priming effects became. A similar significant relationship between nonlinguistic facilitation and language dominance was found in the nonlinguistic task. The analyses also showed that the size of the crosslinguistic and nonlinguistic interference effects were significantly correlated across participants on reaction times.

5.1. Crosslinguistic and within-language effects and their relation with language dominance

Our results replicated the crosslinguistic false cognate interference effect previously reported (Mendoza et al., 2021; von Studnitz & Green, 2002; van Heuven et al., 2008; Vanlangendonck et al., 2020). This effect was found on both accuracy and reaction times in our study: accuracy was lower and reaction times were longer for the false cognate condition compared to the unrelated condition in the PWI task. The fact that we replicated these effects using online testing is notable because online picture-naming studies are still few (Fairs & Strijkers, 2021; Vogt et al., 2022), and the crosslinguistic interference effect had, to our knowledge, not yet been reported in the online setting. The findings of slowed and less accurate naming in the false cognate compared to the unrelated condition confirm the presence of interactive activation during bilingual processing, where the activation of phonologies that are shared across languages results in the activation of conflicting crosslinguistic lexical representations (Costa et al., 2006; Kroll et al., 2006). Relatedly, findings of faster and more accurate naming in the Identity compared to the unrelated condition confirm participants' ability to rely on relevant information (the identity prime) to support lexical access during naming (Costa et al., 2006; Kroll et al., 2006). The presence of these findings in the web-based testing context further points to their stability across less controlled and more ecologically valid testing environments.

An interesting result in our study is that the identity facilitation effect (better performance when the distractor word is identical to the picture name compared to when it is UR to the picture name) increased with increasing English over Spanish dominance. This is expected as the Spanish picture name representation for the more English-dominant participants should be less well known compared to the more Spanish-dominant participants (Gollan et al., 2007). Therefore, providing the picture name through the distractor word should facilitate naming more for the English dominant compared to the Spanish-dominant participants. As such, the current data indicate that language dominance, as indexed through self-reports and objective performance, modulates the accuracy of within-language lexical access.

A more novel, though only marginally significant result in the current study is that, as predicted, the crosslinguistic interference effect on accuracy performance tended to be larger in Spanish–English bilinguals who were more proficient in English than Spanish, and smaller in those who were more proficient in Spanish. It was expected that false cognate distractor words (e.g., the word PLUMA on top of a picture of a plum, where the naming target was *ciruela*) would be more distracting for English-dominant participants. This is because English-dominant participants' English language is potentially more active, and the activation of English representations related in form to the Spanish word may need to be more strongly overcome by interference resolution mechanisms. This is indeed what is proposed by models of bilingual language

Reaction Time (Wald $\chi2(1)$ = .746, *p* = .388) and no interaction with Condition for either of the dependent variables (Accuracy: Wald $\chi2(2)$ = .100, *p* = .951; Reaction Time: Wald $\chi2(2)$ = 2.94, *p* = .230). In the linguistic task, there was a main effect of Absolute Language Dominance on Accuracy (Wald $\chi2(1)$ = 3.91, *p* = .048), where accuracy was lower the more unbalanced our participants' languages were (βraw = −2.09, *SE* = 1.06, *z* = −1.98). There was however no interaction with Condition (Wald $\chi2(2)$ = .391, *p* = .822). Absolute Language Dominance had no effect on Reaction Time in the linguistic task (Wald $\chi2(1)$ = .820, *p* = .365) and there was no interaction with Condition (Wald $\chi2(2)$ = .056, *p* = .972). Removing the bidirectionality of our language dominance score by using its absolute value therefore seems to cause some loss of explanatory power in our data.

processing in which the other language needs to be inhibited when accessing the context-relevant one (e.g., Abutalebi & Green, 2007; Green, 1998) or where a higher activation threshold must be reached to select targets over competing items (Blanco-Elorrieta & Caramazza, 2021). In our study, this effect did not reach significance. Increasing the participant sample size may be needed in that respect as the interaction we found was only marginal on accuracy and absent on reaction times. It is also possible that language dominance effects are more tightly linked to accuracy than reaction time metrics because lower dominance typically entails less stable vocabulary knowledge representations (Bialystok & Luk, 2012; Gollan et al., 2007).

5.2. Nonlinguistic interference and facilitation interact with language dominance

Our results replicated the well-established interference and facilitation effects in the spatial Stroop task on both reaction times and accuracy. Performance was slower and less accurate in incongruent than baseline trials and faster and more accurate in congruent than baseline trials. Presence of these findings from a nonlinguistic cognitive conflict task in a web-based study is consistent with recent findings on similar tasks by Gosselin and Sabourin (2023), despite having a smaller sample size and fewer trials in the present study.

In addition, we observed a significant interaction between the congruency facilitation effect and language dominance. Participants who were more English dominant showed a significantly larger facilitation effect than participants who were more Spanish dominant. There was only a marginal interaction between the Stroop interference effects and language dominance. Given the observed pattern, it is possible that an increase in the sample size would yield a significant interaction between language dominance and Stroop interference as well. For example, in an in-person study with 80 participants, such a correlation was established in a similar sample of Spanish–English bilinguals (Robinson Anthony & Blumenfeld, 2019).

The direction of the interaction between the nonlinguistic Stroop facilitation effect and language dominance is consistent with some but not all previous findings. For example, in an in-person study with Spanish–English bilinguals, Freeman et al. (2022) found that, contrary to the current findings, increased proficiency in English (L2) was associated with *smaller* Stroop facilitation effects. However, Freeman et al. did find larger facilitation effects on the nonverbal Stroop arrows task in a subgroup of participants from Southern California who had more dual-language immersion than a group of Spanish–English bilinguals in the Midwest. This pattern was ascribed to participants being more likely to monitor for facilitatory information from the other language given greater mixed-language input in Southern California. It has been argued that such environmental linguistic circumstances may transfer into the nonlinguistic domain (e.g., Hernández et al., 2010; Sabourin & Vīnerte, 2019). Thus, the current findings of a larger Stroop facilitation effect with increased English over Spanish proficiency can perhaps be understood in the context of participants' presence in language environments where monitoring of facilitatory input from Spanish is still useful with greater English proficiency.

It is also possible that, in the current study, the immediate linguistic context may be critical in explaining the findings. In the current study, the nonlinguistic Stroop task immediately followed the linguistic PWI task. This design was chosen to maximize the time between the tasks requiring Spanish (MINT and experimental PWI) and English (MINT) language skills (see Procedures section for more detail). Across a number of previous studies where cognitive control tasks were interleaved with linguistic tasks, it was found that participants were more successful in resolving *linguistic* ambiguity when the trial was preceded by one where conflict had been experienced from an incongruent cognitive control condition on a *nonlinguistic* Stroop or flanker task (Hsu et al., 2021; Hsu & Novick, 2016; Thothathiri et al., 2018). It is thus possible that performance in the linguistic PWI task in the current study primed participants to recruit cognitive resources that were then online to perform the nonlinguistic Stroop task that followed. For example, participants who were strongly English over Spanish dominant would have benefitted the most from within-language Spanish identity primes to facilitate their Spanish picture naming. Consistently, on the nonlinguistic Stroop task, these English-dominant participants showed the largest facilitation effects, reflecting a processing mode of reliance on congruent facilitatory information. Instead, participants who were the most Spanish over English dominant were more confident in naming Spanish targets and thus relied less on identity primes (confirmed by smaller identity facilitation effects in the linguistic modality). Consistent with their linguistic performance, these Spanish-dominant individuals showed smaller nonlinguistic Stroop facilitation effects, reflecting a processing mode of ignoring irrelevant stimulus dimensions (facilitatory or not). The high similarity between the linguistic and nonlinguistic tasks may also be supporting such a spillover transfer from the linguistic into the nonlinguistic task.

Future research can further tease apart whether the relationships between language dominance and interference/facilitation in the linguistic and nonlinguistic domains continue to mirror each other when the tasks are completed at different times versus when they are performed in sequence and when linguistic and nonlinguistic tasks are less similar and more ecologically valid. If the pattern we observe remains when the tasks are performed at different times, this would point to a more stable transfer pattern that is linked to language experience but not determined by testing context. If the results we observe are specific to when the tasks are performed in sequence, this would suggest that nonlinguistic performance is more temporarily shaped by specific linguistic demands. Regardless, the mirrored patterns of linguistic and nonlinguistic facilitation across the language dominance continuum point to at least partially shared underlying facilitatory mechanisms across domains. The adaptive control hypothesis posits that bilingual processing is driven by the linguistic needs of the environment and shapes related nonlinguistic cognitive control processes, to the extent that these control processes are leveraged during linguistic processing (Green & Abutalebi, 2013). Our results may therefore provide evidence that not only are cognitive control processes shaped by bilingual language processing, but that facilitatory processes outside of language may also benefit from bilingual language processing.

5.3. Overlap between effects in the linguistic and nonlinguistic modalities

Kroll et al. (2006), in discussion of initial findings on false cognate naming, likened the slowdown during naming to an "internally generated Stroop effect" (p. 126, Kroll et al., 2006). Indeed, when examining the relationship between performance in the linguistic and nonlinguistic modalities, our analyses revealed significant correlations between the linguistic and nonlinguistic tasks, both for the size of the interference effects and for the size of the facilitation effects. These correlations were found for reaction times only. This

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is different from what we found previously in the picture-word matching version of the linguistic false cognate paradigm (Mendoza et al., 2021). We note, however, that there were much fewer participants in this previous study compared to the present one. Interestingly, EEG results in the Mendoza et al.'s (2021) study revealed a similar medial frontal response-locked component previously associated with decision-making in their nonlinguistic (Eriksen flanker) and linguistic (receptive false cognate) tasks, suggesting a mirroring of processes engaged in the two modalities. The correlations found here and the EEG patterns on the receptive false cognate task in Mendoza et al. suggest a partial overlap between linguistic and nonlinguistic cognitive control processes. Our results further indicate that, when the number of participants is increased, the performance in the linguistic and nonlinguistic tasks is related at the behavioral level.

The correlations found here across linguistic and nonlinguistic facilitation as well as interference effects on reaction times mirror previous findings, where performance in this spatial Stroop paradigm had been shown to correlate with bilingual language processing (Blumenfeld & Marian, 2013; Freeman et al., 2017; Giezen et al., 2015; Mercier et al., 2014; Robinson Anthony & Blumenfeld, 2019) and with bilingual language experience (Freeman et al., 2022; Kroll et al., 2021; Luk et al., 2011; Robinson Anthony & Blumenfeld, 2019; Xie, 2018). In addition, the correlations identified here are consistent with the finding discussed above, of similar patterns across the linguistic and nonlinguistic domains in how language dominance relates to the magnitude of facilitation and interference effects. Interestingly, the relationship between language dominance and facilitation effects was identified only for response accuracy in both the linguistic and nonlinguistic domains. However, the correlations across domains between facilitation and interference effects were identified only for response times. These findings may reflect a distinction between knowledge versus access: language dominance was more closely tied to whether or not participants had accurate knowledge of items to be produced (i.e., accuracy rates). Instead, the efficiency with which participants could access linguistic and nonlinguistic representations may reflect a general cognitive dexterity that is reflected in reaction times. Importantly, across accuracy and reaction time measures, the current findings reflect a partial overlap in the control mechanisms recruited in the linguistic and nonlinguistic modalities.

5.4. Limitations and future directions

The web-based nature of the current study brings both opportunity and some limitations. Similar to recent web-based studies (Fairs & Strijkers, 2021; Vogt et al., 2022), our naming latencies were longer and the distributions more widespread than in the lab-based experimental setting. This could be due to the online testing modality and because the speed at which stimuli are presented could depend on the specificities of individual participants' devices, including varying internet speeds, screen refresh rates and so forth. Our attrition rate was much smaller (12%) than in these previous studies (29% and over 50%), which is likely because many of our participants were recruited from our classrooms and may have been more invested in following directions compared to participants recruited more broadly.

Web-based testing provides a unique opportunity to reach a wider range of participants and to test bilinguals in the settings where they typically spend time in their everyday lives. It is known that communication context may shift the language mode and the relative activation levels of participants' two languages (e.g., Grosjean, 1998; Marian & Fausey, 2006). It is possible that the settings in which participants completed the study tasks contributed to participants' performance in the current study. For example, it is possible that completion of the study in a bilingual home context would have yielded robust activation of both languages and more stable Spanish performance than might be expected on a majority-English university campus. In future web-based research, more questions could be asked about participants' chosen location and their typical language use when they reside in this location.

One limitation of the current study is that we do not have a symmetrical distribution of language dominance scores. Instead, participants were clustered more strongly in the English dominant than Spanish-dominant range (mean dominance = −.16, SD = .23, range = −.60 to +.43, where negative values suggest English dominance). Having fewer Spanish-dominant than English-dominant participants in the sample is quite common for Spanish–English bilingual participants recruited from American universities and communities (e.g., Freeman et al., 2022; Robinson Anthony & Blumenfeld, 2019). Furthermore, as dominance is treated as a continuum, the midpoint of 0 (i.e., balanced bilingualism) is perhaps an arbitrary point. Instead, the influence of language dominance can be studied by examining how the relative proficiency of one language versus another drives behavior. As the interest in studying bilingualism along gradients of language profiles grows (e.g., Rothman et al., 2023), web-based studies may provide a valuable tool in reaching participants who would not otherwise come to brick-and-mortar research laboratories.

A further limitation, and opportunity for future research is that the current tasks were administered in a fixed order, with purposeful activation of Spanish prior to the experimental task (through performance of the Spanish MINT) and with distance between Spanish and English lexical retrieval tasks, resulting in performance of the nonlinguistic Stroop task immediately following the experimental PWI task. This may have resulted in reduced language dominance effects during the experimental tasks as Spanish was systematically pre-activated through the Spanish MINT ahead of the experimental task. In addition, performance in the nonlinguistic Stroop task may have been affected by performance in the linguistic task, as discussed in Section 5.2. This potential transfer effect may be particularly salient for more English-dominant bilinguals as they showed larger congruency effects overall compared to the more Spanish-dominant participants. As such, the current findings must be interpreted with this testing context in mind and provide an opportunity for manipulation of task order in future studies to determine how effects are modulated by context.

6. Conclusions

In summary, the purpose of the present study was to assess whether an interaction between crosslinguistic false cognate effects, within-language identity priming and language dominance during naming would be visible in the online modality, whether nonlinguistic interference and facilitation effects would be similarly modulated by language dominance, and whether there would be a relationship between cognitive control abilities in the linguistic and nonlinguistic modalities. Our findings confirm both crosslinguistic false cognate interference and within-language facilitation effects on a Spanish naming task with English false cognates. The facilitation effect was enhanced for participants who were more English over Spanish dominant as shown through accuracy performance.

Furthermore, our findings build on previous research suggesting a partial functional overlap between linguistic and nonlinguistic conflict resolution in bilinguals. This overlap is suggested by the correlational link between reaction time linguistic and nonlinguistic interference and facilitation effects. Establishing the role of language dominance as a moderator of facilitation effects *across modalities* is consistent with components of the adaptive control hypothesis, which predicts that bilingual processing is shaped by the environment and in turn shapes related nonlinguistic processes.

Supplementary material. To view supplementary material for this article, please visit http://doi.org/10.1017/S1366728924000774.

Data availability. Please contact the corresponding author for access to the deidentified data.

Competing interest. The authors declare none

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