Affective Science (2021) 2:112–127
https://doi.org/10.1007/s42761-020-00021-x

RESEARCH ARTICLE

Effects of Language Context and Cultural Identity on the Pain Experience of Spanish–English Bilinguals

Morgan Gianola[1] · Maria M. Llabre[1] · Elizabeth A. Reynolds Losin[1]

Received: 26 June 2020 / Accepted: 30 September 2020 / Published online: 30 November 2020

Abstract
While language and culture influence cognition, their role in shaping pain remains understudied. We tested whether language and cultural identification influence pain report among Spanish–English bilinguals. Eighty bilingual Hispanics/Latinos (40 female) experienced painful thermal stimulations, providing pain intensity and unpleasantness ratings, on separate English and Spanish testing days. Participants' skin conductance responses (SCRs) during stimulations served as measures of physiological arousal. Bilingual participants showed larger SCRs and higher pain intensity when speaking the language congruent with their dominant cultural identification. That is, those endorsing more Hispanic cultural identification showed higher pain in Spanish, while US-American-dominant participants demonstrated increased pain in English. Follow-up moderated mediation demonstrated that SCRs mediated language effects on pain ratings for participants endorsing greater Hispanic cultural identification. Together, our results suggest language, cultural associations, and bodily arousal synergistically influence pain evaluations among bilingual people, potentially contributing to well-documented health disparities between Hispanic and non-Hispanic communities.

Keywords Bilingual · Hispanic/Latino · Pain · Culture · Moderated mediation

Introduction

Language is fundamental to human experience, influencing perceptions and behaviors (see Everett, 2013 for a review). In communicating internal experiences, language may shape how we share clinically relevant sensations, such as pain, which is sensitive to social (e.g., Koban & Wager, 2016) and cognitive influences (e.g., Czerniak et al., 2016). Among US Hispanics/Latinos, interplays between language and pain may have particular clinical relevance. Hispanics/Latinos ("Hispanics" hereafter) comprise the largest US bilingual population (U.S. Census Bureau, 2017) and face disparities in pain treatment (Anderson et al., 2009; Meghani et al., 2012). We investigated how English- vs. Spanish-speaking contexts alter Spanish–English bilingual Hispanics' evaluations of and physiological responses to experimentally induced pain. As language is integral to cultural experience (e.g., Lynch, 2009), we further assessed how language effects on pain are tied to bilingual participants' identification with cultures associated with each language.

US Hispanics are particularly relevant to study in the context of pain processing. Across clinical pain studies, Hispanics report greater pain severity (Hollingshead et al., 2016) and life interference than non-Hispanic whites while also being less likely to receive analgesics to treat pain (Anderson et al., 2009), particularly non-traumatic/non-surgical pain (Meghani et al., 2012; see Campbell & Edwards, 2012 for a review). In one experimental pain study, Hispanics demonstrated lower pain tolerance compared with non-Hispanic whites; moreover, stronger identification with Hispanic culture corresponded with greater pain sensitivity (i.e., lower tolerance ratings; Rahim-Williams et al., 2007). Such findings led Hollingshead et al. (2016) to develop a model of the Hispanic pain experience which centers both psychobiological and sociocultural contributors; the latter of these components were a central focus in the design and interpretation of the present investigation.

Handling editor: Shigehiro Oishi

✉ Morgan Gianola
mgianola@miami.edu

[1] Department of Psychology, University of Miami, Miami, FL, USA

Language, as a defining feature of many cultures, likely plays a central role in sociocultural contributions to these pain effects among Hispanics. Pain is typically clinically evaluated via verbal report (Breivik et al., 2008; Hjermstad et al., 2011), and language concordant care is associated with improved patient comfort and healthcare satisfaction (Ali & Johnson, 2017). One Swiss epidemiological study of 1,200 plus back pain patients found that German speakers were more likely to rely on active coping strategies (e.g., "aspiration to improve"), while French speakers engage more passive pain coping (e.g., "acquiescence to the condition"; Schulz et al., 2013). The authors interpreted this outcome to be the result of varied cultural tendencies which differentiate the Swiss microcultures associated with each language. Thus, cultural features covarying with language use can meaningfully alter the way we evaluate and respond to pain in ourselves and others. However, the quasi-experimental nature of these comparisons (i.e., no random assignment to different language categories) underscores the need for within-subject experimental designs.

Among Spanish–English bilinguals, language context (i.e., English or Spanish experimental conditions) can alter self-reported anxiety (Guttfreund, 1990) and attentional focus (Schonberg et al., 2019), both processes known to causally influence experimental pain report (Legrain et al., 2009; Tang & Gibson, 2005). Linguistic distinctions across languages could further contribute to pain variability. For example, Spanish grammar may foreground the self and/or emphasize pain's ongoing nature (e.g., *me dolía*—"It was hurting me") compared with English phrasings (e.g., "that hurt"). As a key feature of Hispanic culture (Taylor et al., 2012), language usage may meaningfully contribute to pain experiences. Further study could examine how other cultural patterns, e.g., *familismo* (i.e., placing familial needs ahead of individual needs) or *machismo* (i.e., masculine aggression and strength) commonly expressed in Hispanic cultures (Ingoldsby, 1991) may influence factors, such as verbal suggestibility or coping strategies, which are known to alter pain responses (Jensen et al., 1991; Ružić et al., 2017).

Here, we investigated how language and cultural identification influence pain report and physiological responses within Spanish–English bilinguals. We used thermal stimulations to evoke pain and recorded mean skin conductance response amplitude (mSCRa) as a measure of physiological arousal. We predicted bilingual participants would report higher pain in Spanish (compared with English) due to a greater centering of the self in expressions related to the pain experience in Spanish; such expressions may engage cognitive reappraisal mechanisms which can upregulate pain sensations and responses (Woo et al., 2015). Because, similar to pain report, pain-evoked skin conductance responses are affected by psychological manipulations (Koban & Wager, 2016; Reicherts et al., 2016), if language impacts experiential aspects of pain, we predicted mSCRa would mirror differences in pain ratings; conversely, if language affects pain only at the communicative level, physiological responses would be unlikely to vary across languages. Since stronger identification with Hispanic culture has been linked to greater pain sensitivity (Rahim-Williams et al., 2007), we predicted language effects would be largest among Hispanic-identified bilinguals. We conducted moderated mediation analyses to clarify the mechanisms of language effects on pain report across cultural identities.

Methods

Participants

Participants in this experiment were $N = 96$ (51 female) healthy adults ages 18–51 recruited from the University of Miami or surrounding Miami-Dade County. All participants self-identified as bicultural and reported being fluent or native speakers of both English and Spanish, having acquired their second language by age 10, a common cutoff age for early vs. late bilingualism (Luk et al., 2011). All participants confirmed that they identified as Hispanic and/or Latino/a and considered themselves to be bicultural. Individuals over age 55 were excluded from participation due to documented alterations in pain sensitivity in this age group (Riley 3rd et al., 2010). Informed consent was acquired from all participants in both English and Spanish. All study procedures were approved by the University of Miami Institutional Review Board and participants were compensated for their involvement.

Participants were excluded for past or current pain conditions or for taking medications that may affect pain perception. The total of 96 participants includes 12 pilot participants, three participants who only completed half the study, and one participant whose data were removed due to taking a pain medication before the study session. Hence, data from 80 participants (40 female) with a mean age of 29.0 ± 8.8 are included in the analytic sample.

Sample size was decided a priori based on effect sizes observed between English and Spanish conditions in prior research (see Fausey & Boroditsky, 2011; and Ramírez-Esparza et al., 2006 for smallest and largest effect sizes respectively). Sample sizes to acquire a power of 0.80 were calculated using the GPower software (Erdfelder et al., 1996). We determined that a sample of 80 subjects would permit the detection of effects as small as Cohen's d of 0.32 (the lower end of the effects reported in the literature) with a power of 0.80.

Study Design

Employing a within-subject design, participants received painful thermal stimulations and provided pain ratings during two separate English and Spanish laboratory sessions, each lasting 1.5 to 2 h. Four (two female) fully bilingual experimenters guided all participants through the study procedures. Each participant saw only one gender-matched experimenter throughout their study participation in addition to speaking with one of the authors (MG) during a brief concluding interview. Participants interacted with and received painful thermal stimulations from gender-matched experimenters to control for known effects of experimenter gender on pain report (Aslaksen et al., 2007; Levine & De Simone, 1991). Self-report acculturation metrics were collected at the end of each session, allowing us to assess the role of cultural identification (i.e., relative endorsement of cultural aspects tied to each language) on the pain experience.

During one session, all study materials and interactions were presented in English, while the other session was conducted entirely in Spanish. Session order was counterbalanced across participants. Additionally, within each session, participants received half of the pain stimulations before and half of the stimulations after a language-congruent "cultural priming" task in which they viewed culturally evocative images (similar to those of Chiao et al., 2010; Lechuga, 2008; Morris & Mok, 2011; Ng et al., 2010). This procedure was meant to activate either participants' US-American (English session) or Hispanic (Spanish session) cultural identity (see *Experimental Protocol* in the supplement for more details on the cultural priming procedure). Participants' electrodermal activity (EDA) and electrocardiogram (ECG) were recorded throughout both study sessions as measures of physiological responses to the pain stimulations. All other procedures were identical between the two sessions, with the exception that informed consent was only acquired during the first session and a study completion survey and concluding interview were only completed during the second session. Initial analysis revealed no significant effects of the cultural priming manipulation on the pain outcomes considered here (see *Regression Models Testing for Cultural Priming Effects on Pain Outcomes* in the supplement for results of these analyses). Session segment (i.e., if stimulations occurred pre- or post-priming) was statistically controlled in the models presented here but is not a primary focus of these analyses. The ECG data and cultural priming manipulation from this experiment are outside the scope of the present investigation and will be considered in future analyses.

Separate English and Spanish programs created with the stimulus delivery and control software, Presentation (Neurobehavioral Systems, Inc.), were used to coordinate heat stimulations and the various forms of data collected during each experimental session. These programs also served as a script for the experimenter to guide participants through the experimental protocol. All Spanish study materials (e.g., consent forms, surveys, study scripts) were constructed using a forward and back translation process. English documents were translated into Spanish, then Spanish versions were back translated into English by another bilingual researcher. Any discrepancies between translations were resolved via discussion among all researchers to determine the final versions (as suggested in Prieto, 1992). The study scripts were written such that both the content and wording given to participants remained consistent across experimenters and parallel between language conditions. For example, the Spanish word *esperar* ("expect") can also mean "wait" or "hope for." Thus, instead of being asked what they "expect," participants rated what they "anticipate" (*anticipar)* from the stimulations in both language conditions.

Session Overview

Each experimental session consisted of five portions. First, during the "heat training" (Fig. 1[A]), the experimenter explained to the participant the types of thermal stimulations they would receive and the ratings made throughout the study. This time served as an opportunity for the experimenter to build rapport with the participant, conversing in the session language. Second, during "pre-priming trials" (Fig. 1[B]), participants provided distinct ratings for each of three types of painful thermal stimulations: threshold (× 4 trials), tolerance (× 4 trials), and suprathreshold stimulations (× 8 trials). Each thermal stimulation was delivered to one of eight skin sites on the participants' left volar forearm using a 16 mm × 16 mm Medoc peltier contact thermode from a Pathway Pain & Sensory Evaluation System (Medoc, Inc., Haifa, Israel). Suprathreshold stimulations lasted 8 s in total, comprising 4.5 s at one of two predetermined temperatures (47 °C or 49 °C; × 4 trials at each temperature) previously identified as above most individuals' pain threshold (Edwards & Fillingim, 1999) flanked by 1.75 s ramp periods to get to the target temperature and return to a 38 °C baseline. To ensure participant safety and comfort, participants could request that the experimenter remove a suprathreshold stimulation before completion if it became intolerable. Whether participants removed a stimulation early or not was included as a binary control variable in later analyses (see the "Data Analysis" section); in total, 107 suprathreshold stimulations (4.18% of all trials) were removed early. Collected pain ratings included the point at which the participant first felt pain (i.e., pain threshold) for threshold trials, the point at which the pain became intolerable (i.e., pain tolerance) for tolerance trials, and numerical ratings of overall pain unpleasantness and pain intensity after each suprathreshold trial. Participants rated both the intensity and unpleasantness of the pain they experienced during each stimulation. These two ratings allowed us to separately assess language effects on different aspects of the pain experience. Specifically, in prior experimental pain literature, intensity ratings have been associated with the sensory–discriminative aspect of pain while unpleasantness ratings are used to assess pain's affective–motivational component

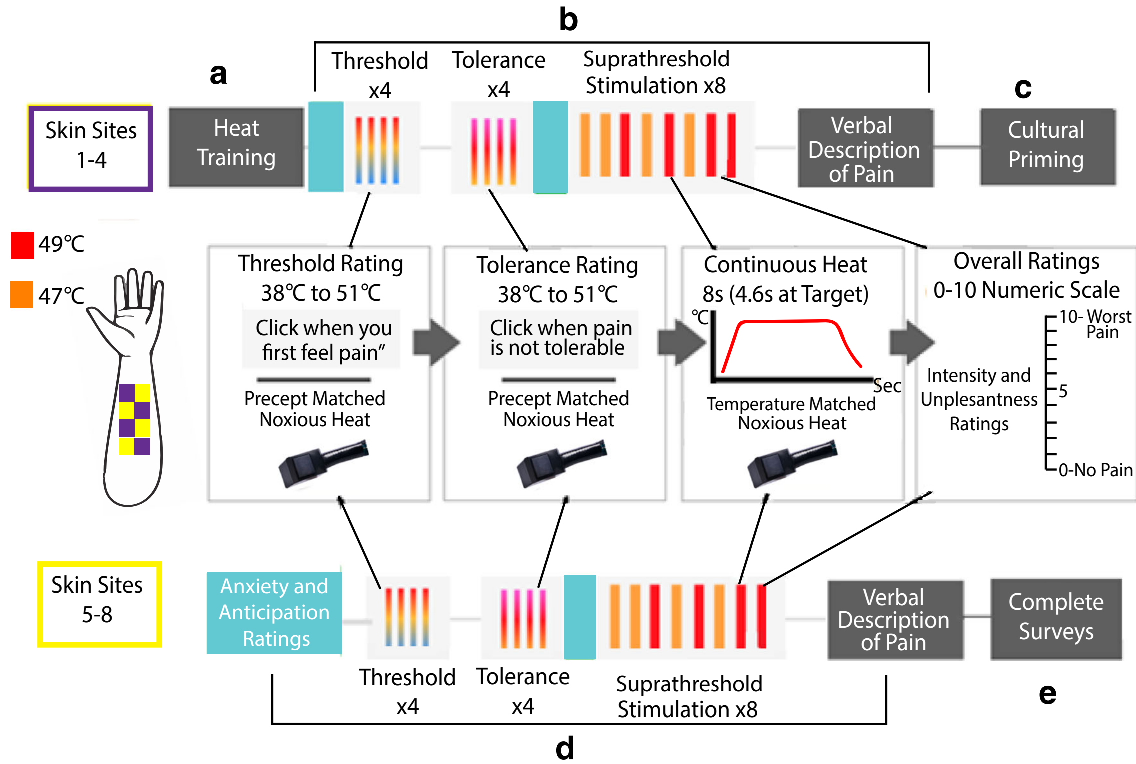

Fig. 1 Procedure overview for single study session. Light blue bars denote participants rating their current anxiety level and anticipated pain for upcoming stimulations. Pre-priming stimulations (B) were administered to skin sites 1–4 (purple), whereas post-priming trials (D) were administered to skin sites 5–8 (yellow)

(Auvray et al., 2010). As anxiety and expectations are both known to influence evaluations of experimentally induced pain (Ružić et al., 2017; Tang & Gibson, 2005), participants also provided anxiety and pain anticipation ratings, though these ratings are not considered in the present analyses. Open-ended verbal descriptions of the pain experience were collected to assess the presence of language-congruent differences in pain coping (Schulz et al., 2013).

Third, during "cultural priming," the experimenter led a conversation around culturally relevant questions and the viewing of culturally salient images with the participant (Fig. 1[C]). This portion was designed to prime the participant's language-congruent cultural mindset (i.e., US-American culture for English sessions, Hispanic culture for Spanish sessions). Fourth, during "post-priming trials" (Fig. 1[D]), participants received an identical series of heat stimulations and completed the same evaluations as during pre-priming trials (i.e., pain threshold, pain tolerance, suprathreshold intensity and unpleasantness ratings, anxiety and anticipation ratings, verbal descriptions of pain). To reduce habituation or sensitization effects resulting from repeated stimulation (Jepma et al., 2014), pre- and post-priming trials were delivered at distinct skin sites.

Finally, participants completed various surveys in the language of the study session via Qualtrics (Fig. 1[E]). The full list of surveys completed and relevant citations are available in the supplement (see *Experimental Protocol*). The surveys of interest for the present analyses include the Abbreviated Multidimensional Acculturation Scale (AMAS; Zea et al., 2003) and Hispanic Community Health Study/Study of Latinos Sociocultural Questionnaire (SOL SC; Sorlie et al., 2010). These acculturation measures were used to assess participants' integration and identification with various aspects of US-American and Hispanic culture. Present analyses are limited to participants' pain intensity and unpleasantness ratings and EDA recordings during suprathreshold trials.

Data Analysis

Unless otherwise noted, all data were compiled and analyzed in R Studio version 3.6.1 (R Core Team, 2019).

Continuous EDA recordings were acquired throughout the experimental sessions with EL507 sensors placed on the left index and middle fingers with isotonic electrode gel to maintain contact (Gel 101, BIOPAC Systems Inc.). Signals were sent via a Bionomadix wireless EDA transmitter and receiver module pair which interfaced with a MP150 data acquisition platform read into the AcqKnowledge software (version 4.4.2, BIOPAC Systems Inc.). EDA time series were batch processed using the continuous decomposition analysis feature of the Ledalab software toolbox V3.2.5 (Benedek & Kaernbach, 2010) for MATLAB (version R2017a). Briefly, data originally acquired at 1000 Hz were down-sampled to 50 Hz, smoothed with the adaptive smoothing tool, and submitted to the continuous decomposition analysis which split the signal into separate tonic and phasic components. Events were defined from 5 s after the Medoc thermode received the signal to initiate a heat stimulation (allowing 4 s of equipment delay and 1 s for initiation of physiological response after heat onset) to 15 s after the start signal, thus including the stimulation period and a few seconds after the end of the heat stimulation. Phasic signals (i.e., the signal remaining after accounting for baseline tonic activity) exceeding a threshold of 0.01 microsiemens (μS) within the response window were recorded as a skin conductance response (SCR). The mean amplitude of this phasic skin conductance response across the response window (mSCRa; an estimate of the underlying sudomotor nerve activity) served as our primary implicit biological indicator of participants' pain-evoked physiological arousal for each heat stimulation trial (Benedek & Kaernbach, 2010). This mSCRa metric was log transformed (natural logarithm of mSCRa in μS) in order to meet the assumptions of the analyzed linear models. This transformation did not affect the rank order of mSCRa across trials or participants.

The AMAS was scored according to previously documented procedures by averaging responses in each subscale, resulting in separate US acculturation and "culture of origin" (i.e., Hispanic) acculturation scores (Zea et al., 2003). The SOL SC was scored by summing item responses within each subscale. Some items and subscales were reverse scored in order to make lower values always represent greater endorsement of dimensions of Hispanic culture. Missing responses were imputed with that individual's mean score for the corresponding subscale. As most participants answered all survey questions, no more than two items required mean imputation for any single participant. AMAS and SOL SC scores were combined into one composite "cultural dominance" metric per session for each participant. This value served as a potential moderator of language effects on pain outcomes. Specifically, the AMAS culture of origin subscale was subtracted from the US culture subscale and rescaled to produce one continuous measure. Lower scores corresponded to greater Hispanic cultural identification (including use of the Spanish language); higher scores denoted greater US-American cultural identification (and English language use). Similarly, the SOL SC familism subscale was reverse scored and combined with the acculturation subscale such that lower scores denoted greater endorsement of familism and Hispanic culture. An average (weighted by the number of questions used from each survey) was calculated between the AMAS and SOL SC metrics to produce the cultural dominance measure. As all included items from the two surveys dealt with distinct aspects of cultural knowledge and identity, this weighted average approach provided equal weight to each item. We chose not to combine *Z* transformed total survey scores as this would have implied double weighting of similar items appearing in both surveys and weighting items from the shorter survey more heavily. The AMAS and included portions of the SOL SC metrics were significantly correlated during both English ($r = 0.38$, 95% CI [0.17, 0.55], $t(78) = 3.61$, $p < .001$) and Spanish ($r = 0.36$, 95% CI [0.16, 0.54], $t(78) = 3.43$, $p < .001$) sessions, suggesting they reflected comparable constructs. As our sample size was not large enough for adequate use of factor analysis (Mundfrom et al., 2005; Tabachnick et al., 2013), this composite metric was employed to account for a greater variety of culturally relevant factors (e.g., familism, language usage, cultural awareness) than captured by either survey alone. This composite score consisted of a single value, on a scale theoretically ranging from − 3 (high Hispanic cultural dominance) to + 3 (high US-American cultural dominance), with 0 representing balanced cultural identity and language usage. In reality, participants' cultural dominance values ranged from − 1.7 to + 0.9, with more people showing relative US-American cultural dominance (Fig. 2). These cultural dominance scores did not vary significantly between English and Spanish sessions (paired *t* test; $t(79) = -0.43$, $p = .667$) and were not strongly correlated with age in either condition (English: $r = .18$, 95% CI [− 0.04, 0.38], $t(78) = 1.59$, $p = .116$; Spanish: $r = .12$, 95% CI [− 0.11, 0.33], $t(78) = 1.04$, $p = .302$).

Trial level pain outcomes (i.e., intensity and unpleasantness ratings, mSCRa) from suprathreshold stimulations were first analyzed via separate linear mixed effects models using the *lme4* package in R (Bates et al., 2015). Random intercepts across participants were included to account for variability in participants' general pain sensitivity, with participants nested within the experimenter who conducted their sessions. Due to equipment errors leading to signal dropout, 132 trials of mSCRa data (5.16% of the sample) are missing. Intensity and unpleasantness models contained no missing data. Control variables in these models included the study session (first or second), session segment (pre- or post-priming trials), temperature (47 °C or 49 °C), trial number (1–8), and a binary variable denoting whether a stimulation was removed before completion ("removal"). Additionally, participant gender and age were included to account for known differences in pain ratings across these demographic variables (Lautenbacher et al., 2017; Ostrom et al., 2017). Session language, dummy coded as 0 for English and 1 for Spanish, served as the primary predictor of interest. The composite cultural dominance measure was included in each model and tested as a potential moderator of language effects by incorporating language by cultural dominance interaction terms in addition to main effects. All models were screened for influential outliers at the participant and trial level using a recommended cutoff of Cook's distance ≥ 4/N (Bollen & Jackman, 1985). All models were analyzed with outliers excluded from the dataset, but all

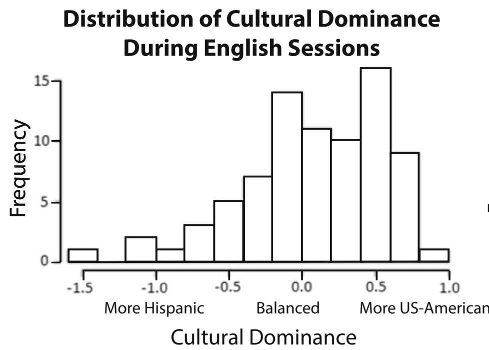

Fig. 2 Distribution of participants' composite cultural dominance scores during English (left) and Spanish (right) experimental sessions. Cultural dominance values were calculated from a weighted average of acculturation survey scores (AMAS and SOL SC). Negative values denote greater Hispanic cultural dominance, while positive values correspond to greater relative endorsement of US-American culture

primary results remained consistent. After verifying that outlier observations were not driven by data collection or measurement error, all analyses retained potentially influential data points, consistent with views on statistical best practices for outlier analysis (Zuur et al., 2010).

Upon initial inspection of these models, a similar pattern of language effects across cultural dominance levels was observed for intensity ratings and mSCRa (see the "Results" section). We thus conducted follow-up moderated mediation analyses to assess the degree to which pain evoked physiological arousal (i.e., mSCRa) indirectly contributed to language effects on pain ratings, and the extent to which this pattern differed across participants' cultural identification. A mediation relationship was proposed due to the temporal precedence between mSCRa (measured during stimulations) and pain ratings (collected after each stimulation) and because physiological signals are known to impact subsequent behavior and emotions (Critchley & Garfinkel, 2017). For these analyses, linear mixed effects models with random intercepts for participant (nested within experimenter) and fixed effects of all control variables (i.e., session, segment, trial number, temperature, removal, age, and gender) were fit to unpleasantness, intensity, and mSCRa outcomes using the *lmer* function of the *lme4* R package (Bates et al., 2015). The residuals from these models were analyzed according to the moderated mediation pathway outlined in Fig. 3.

Mediation effects for both pain unpleasantness and intensity outcomes were compared at one standard deviation above and below the mean cultural dominance value, typical levels for testing conditional mediation in moderated mediation analyses (Preacher et al., 2007). Hence, mediation effects were tested in models with cultural dominance scores centered at + 0.57, reflecting US-American dominance, and at − 0.40, reflecting Hispanic dominance. Conditional models comparing scores at the mean cultural dominance score are described in the supplement (*Conditional Mediation for Balanced Biculturals*). Path coefficients were estimated using *lm()* linear regression models (R base package; R Core Team, 2019) and corroborated against structural equation models fit with the *lavaan* package (Rosseel, 2012). Conditional mediation and direct effects were compared across moderator conditions (i.e., US-American and Hispanic cultural dominance) using the *test.modmed* function of the *mediation* package (Tingley et al., 2014). Bootstrapped confidence intervals were calculated from 1,000 simulations for individual conditional models and 2,000 simulations for comparisons of conditional mediation effects. Residual-based mediation models were analyzed to account for the nested structure of participants with the experimenter conducting their sessions, which the *mediation* package was not able to incorporate. These residual-based models are presented in the main text for ease of interpretation, though analyses testing moderated mediation relationships in models including control variables (except experimenter) are available in the supplement (see *Alternative Analysis Results*). These models were interpreted according to the mediation framework outlined by Zhao et al., (2010).

Results

Initial Manipulation Checks

We first note that multiple control variables included in the models predicted the tested pain outcomes (Table 1). Pain unpleasantness and intensity ratings were significantly correlated ($r = .919$, 95% CI [0.913, 0.925], $t(2558) = 118.07$, $p < .001$) and predicted by the same control variables: age, session, temperature, and removal (i.e., whether the participant stopped the stimulation before trial completion). Participants rated stimulations as more intense and unpleasant during their first session (regardless of language), when stimulations were at higher temperatures, and when stimulations were removed early. Pain ratings also tended to be lower for older participants. These same variables produced corresponding effects on participants' pain-evoked physiological arousal (measured via mean skin conductance response amplitude, mSCRa). Physiological arousal also decreased across trials within a segment and from pre-priming to post-priming trials, in line with expected

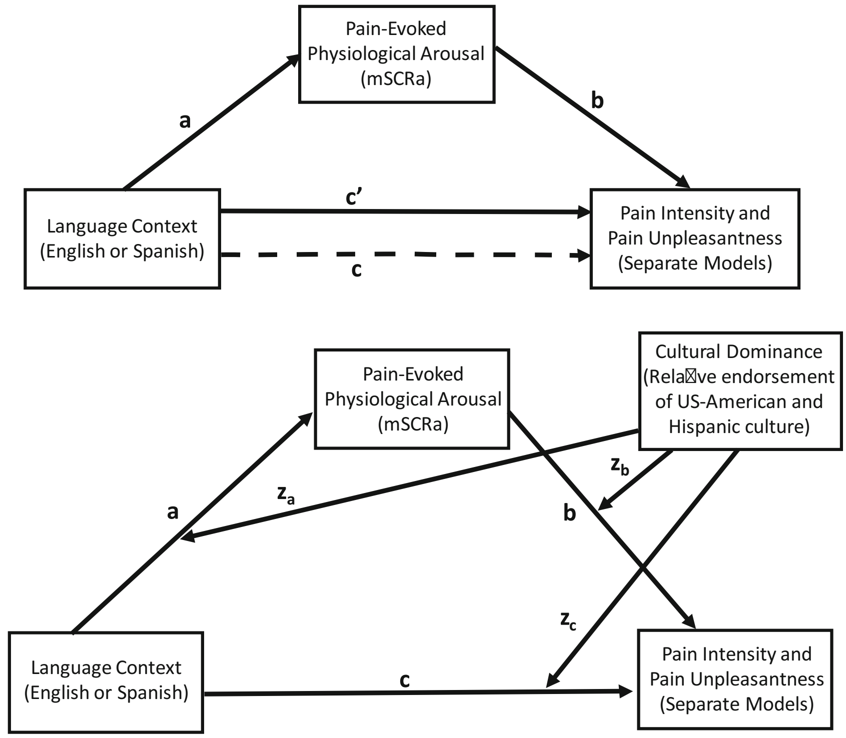

Fig. 3 The hypothesized mediation (top) and moderated mediation (bottom) models analyzed in this study. Each model was tested with two separate outcome variables: pain unpleasantness and pain intensity ratings. mSCRa, mean skin conductance response amplitude

habituation effects. As session segment (pre- or post-priming) did not significantly predict either intensity or unpleasantness ratings (*p*s > .50), switching stimulation sites between segments appears to have prevented habituation effects from influencing explicit pain ratings. These results indicate that the heat pain manipulation functioned as expected, and the inclusion of theses control variables in the models reduces the potential for the language effects (discussed below) to result from confounds of the heat pain paradigm. Furthermore, participants' mSCRa was significantly positively correlated with their ratings of pain intensity ($r = .341$, 95% CI [0.305, 0.376], $t(2426) = 17.87$, $p < .001$) and unpleasantness ($r = .335$, 95% CI [0.300, 0.370], $t(2426) = 17.54$, $p < .001$). This relationship signified that participants' pain-evoked physiological arousal tracked well with self-reported pain measures and was predicted by variables which also affect pain ratings, reinforcing its use as an indicator of implicit pain responses.

Language Effects on Pain Intensity Are Moderated by Cultural Dominance

Interestingly, cultural dominance moderated the effects of the language manipulation on pain intensity ratings. Significant main effects of language and cultural dominance did not emerge among any of the three pain outcomes (intensity, unpleasantness, physiological arousal; all *p*s > .25; Table 1). However, intensity ratings tended to differ across language conditions for participants with stronger preferences for a single culture. Particularly in the Spanish condition, participants who showed greater endorsement of their Hispanic (compared with US-American) cultural identity provided higher intensity ratings than their more US-American-identified counterparts. Further, intensity ratings across cultural dominance scores showed a weaker inverse pattern in the English condition, with more US-American-identified participants providing higher intensity ratings than those more strongly endorsing Hispanic culture. The language by cultural dominance interaction for pain intensity ratings ($B = -0.46$, SE = 0.132, $p < .001$) is depicted in Fig. 4a by the significant difference in slopes across language conditions. Overall, participants endorsing high Hispanic cultural dominance showed the largest effect of the language manipulation. During Spanish sessions, these participants rated suprathreshold stimulations as ~ 0.3–1.0 points more intense (10-point scale) on average compared with their English session (Fig. 4a). Conversely, those reporting higher US-American dominance exhibited *lower* intensity ratings during Spanish sessions, while those with balanced cultural identification (cultural dominance values near 0) provided similar intensity ratings regardless of language. This moderation relationship explains the lack of main effect for language, as language context did not influence all participants equally or in the same direction. Estimates of Cohen's *d* suggest that the language by cultural dominance interaction on intensity ratings ($d = -0.138$) was roughly comparable with the drop in ratings from the first to second sessions ($d = -0.171$). This finding indicates that the combination of language and cultural identification can affect explicit pain

Table 1 Fixed effects variables relationships with pain outcomes

Outcome predictors	*B*	95% CI	SE	*t* value	*p* value	Cohen's *d*
Pain unpleasantness						
Session*	− 0.16	[− 0.29, − 0.04]	0.064	− 2.557	.011	− 0.102
Segment[a]	0.02	[− 0.10, 0.14]	0.063	0.310	.757	0.012
Temperature*	3.13	[3.00, 3.26]	0.065	48.328	< .001	1.943
Removal*	1.22	[0.83, 1.61]	0.199	6.089	< 0.001	0.242
Trial	0.008	[− 0.02, 0.04]	0.014	0.610	.542	0.025
Age (in years)*	− 0.05	[− 0.10, − 0.01]	0.023	− 2.315	.023	− 0.442
Gender[b]	− 0.45	[− 1.61, 0.72]	0.652	− 0.695	.560	− 0.988
Language[c]	0.01	[− 0.11, 0.14]	0.065	0.206	.837	0.008
Cultural dominance	− 0.26	[− 0.73, 0.21]	0.241	− 1.080	.280	− 0.066
Language × cultural dominance	− 0.08	[− 0.36, 0.18]	0.136	− 0.652	.514	− 0.026
Pain intensity						
Session*	− 0.27	[− 0.39, − 0.14]	0.062	− 4.271	< .001	− 0.171
Segment[a]	0.04	[− 0.08, 0.16]	0.062	0.632	527	0.025
Temperature*	3.10	[2.98, 3.22]	0.063	49.121	< .001	1.975
Removal*	0.88	[0.50 1.26]	0.194	4.516	< .001	0.180
Trial	0.004	[− 0.02, 0.03]	0.013	0.327	.744	0.013
Age (in years)*	− 0.05	[− 0.10, − 0.01]	0.022	− 2.488	.014	− 0.473
Gender[b]	− 0.39	[− 1.22, 0.40]	0.498	− 0.792	.513	− 1.136
Language[c]	0.06	[− 0.06, 0.19]	0.063	1.021	307	0.041
Cultural dominance	0.08	[− 0.37, 0.54]	0.235	0.359	719	0.022
Language × cultural dominance*	− 0.46	[− 0.72, − 0.20]	0.132	− 3.442	< .001	− 0.138
Pain-evoked physiological arousal (mSCRa)						
Session*	− 0.16	[− 0.21, − 0.10]	0.030	− 5.232	< .001	− 0.216
Segment*[a]	− 0.30	[− 0.36, − 0.24]	0.029	− 10.307	< .001	− 0.426
Temperature*	0.88	[0.82, 0.94]	0.030	29.567	< .001	1.222
Removal*	− 0.24	[− 0.42, − 0.07]	0.089	− 2.741	.006	− 0.112
Trial*	− 0.08	[− 0.10, − 0.07]	0.006	− 12.994	< .001	− 0.538
Age (in years)*	− 0.05	[− 0.07, − 0.03]	0.010	− 4.443	< .001	− 0.839
Gender[b]	0.19	[− 0.22, 0.60]	0.199	0.971	.335	0.227
Language[c]	0.03	[− 0.03, 0.09]	0.030	0.946	.344	0.039
Cultural dominance	− 0.06	[− 0.27, 0.15]	0.109	− 0.539	.590	− 0.032
Language × cultural dominance*	− 0.16	[− 0.28, − 0.04]	0.062	− 2.657	.008	− 0.110

B slope, *CI* confidence interval, *SE* standard error, *mSCRa* mean skin conductance response amplitude

*Variables with significant ($p < .05$) slopes

[a] Segment denotes comparison between pre-priming and post-priming trials, with negative values corresponding to higher pain outcomes pre-priming

[b] Negative values for gender denote higher pain outcomes in women

[c] Language coded as 0 for English, 1 for Spanish; negative values denote higher pain outcomes in English

evaluations nearly as strongly as the psycho-physiological effect of prior exposure to the painful experience.

Cultural Dominance Moderates Language Effects on Pain-Evoked Physiological Arousal

A similar moderation of language effects by cultural dominance emerged for participants' pain-evoked physiological arousal (i.e., mSCRa) during suprathreshold stimulations ($B = -0.16$, SE = 0.062, $p = .008$). Again, the effect was most pronounced during Spanish sessions, where more culturally Hispanic-identified bilingual participants showed significantly greater pain-evoked arousal than those who endorsed stronger US-American cultural identity. The relationship between cultural dominance and mSCRa was weaker for English sessions, becoming non-significant, though the trend remained in

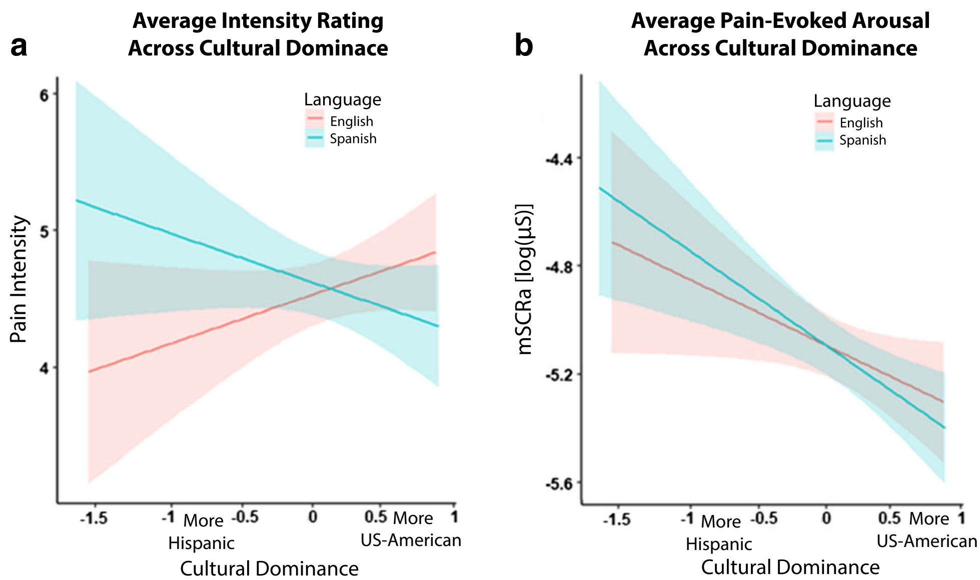

Fig. 4 Plotted relationships between pain outcomes and cultural dominance values during English and Spanish study sessions. **a** Pain intensity ratings during suprathreshold trials across cultural dominance scores and language conditions. **b** Pain-evoked physiological arousal assessed as mSCRa across cultural dominance scores and language conditions. Log-transformed mSCRa (measured in microsiemens) are plotted on the *y*-axis; lower values denote lower mSCRa. Note the error bands for the red English line include the potential for a flat relationship (non-significant effect), whereas this is not the case for the blue Spanish line. Negative cultural dominance values reflect greater endorsement of Hispanic compared with US-American culture, while positive values reflect the opposite. Cultural dominance scores near 0 represent balanced cultural identification. Error bands denote standard error of the mean

the same direction (i.e., larger mSCRa among more Hispanic-dominant participants). This pattern of physiological arousal resulted in a significant language by cultural dominance interaction, visualized as a steeper slope for the Spanish line in Fig. 4b; while the English line tends in the same direction, the error range includes the possibility of a flat relationship. This outcome also explains the lack of a significant main effect of cultural dominance on physiological arousal (Table 1). The crossover point for this relationship was once again near the cultural dominance score of 0, meaning that participants who endorsed roughly equal US-American and Hispanic cultural values exhibited similar pain-evoked arousal in both language contexts. Hispanic-dominant participants produced larger mSCRa in Spanish compared with English, whereas more US-American-dominant participants displayed the opposite effect. The effect size for this interaction ($d = -0.110$) was comparable to removing a stimulation early ($d = -0.112$), demonstrating that language and cultural variables can lead to physiological changes as profound as changes in (the duration of) the painful stimulus itself. In total, participants tended to report more intense pain and show greater physiological arousal in the language condition associated with their more dominant culture.

In contrast to intensity ratings and pain-evoked physiological arousal, neither language, cultural dominance, nor their interaction significantly predicted pain unpleasantness during suprathreshold stimulations (all $ps > .25$). Table 2 summarizes the random effects of these three models along with the variance explained by the fixed effects ("marginal R^2") and the full models including random effects of participant nested within the experimenter conducting their sessions ("conditional R^2"). For all three models, approximately 40% of the variance in pain outcomes was observed within subjects while ~ 60% was between subjects.

No Mediation of Language Effects on Pain via Physiological Arousal Across Full Sample

Given the similar pattern of results observed in the pain intensity and pain-evoked physiological arousal outcomes, we tested whether mSCRa (our metric of physiological arousal) mediated the relationship between language conditions and explicit pain ratings. Despite having initially found no direct language effect on either pain unpleasantness or intensity ratings, these mediation models were considered because indirect effects may emerge in the absence of total effects (Zhao et al., 2010), and testing meditation models may offer more power to detect certain effects (O'Rourke & MacKinnon, 2015).

Unsurprisingly, language was not predictive of physiological arousal (non-significant path *a*; $p > .60$) and did not significantly alter pain intensity or unpleasantness ratings without the interaction of the cultural dominance variable (non-significant path *c*'s for both models; $ps > .70$). However, path *b* was shown to be significant, as physiological arousal (i.e., mSCRa) predicted both intensity and unpleasantness ratings (unpleasantness: $B = 0.436$, $SE = 0.045$; intensity: $B = 0.390$,

Table 2 Estimates of random effects parameters across pain outcome models

Outcome predictors	Variance	Standard deviation	Marginal R^2	Conditional R^2
Pain unpleasantness			.318	.726
Participant (nested within experimenter)	3.58	1.89		
Experimenter	0.24	0.49		
Residual	2.57	1.60		
Pain intensity			.327	.722
Participant (nested within experimenter)	3.39	1.84		
Experimenter	0.07	0.27		
Residual	2.43	1.56		
Pain evoked physiological arousal (mSCRa)			.252	.700
Participant (nested within experimenter)	0.76	0.88		
Experimenter	< 0.001	< 0.001		
Residual	0.51	0.72		

Values rounded to two decimals. All models showed significant χ^2 statistics for random effects of participant ($ps < .0001$) and non-significant effects of experimenter

mSCRa mean skin conductance response amplitude

SE = 0.044; both $p < .001$) when controlling for language. No significant indirect (i.e., mediation), direct, or total effects emerged for either model. A similar pattern of results was also found when testing conditional models centered at the mean cultural dominance (see supplement *Conditional Models for Balanced Biculturals*). This result was expected given that inverse language effects across the cultural dominance spectrum would cancel out when averaging across all participants. Therefore, we sought to account for different directions of language effects across participants endorsing different patterns of cultural identification by testing the moderated mediation model depicted in the bottom of Fig. 3.

Language Effects on Pain Ratings Are Mediated by Physiological Arousal for Hispanic-Dominant Participants

Pain-evoked physiological arousal significantly mediated the relationship between language context and pain ratings (both intensity and unpleasantness) for culturally Hispanic-dominant participants. Language context directly influenced pain intensity ratings for both culturally Hispanic and US-American-dominant participants, whereas unpleasantness ratings were not directly influenced by language context at either end of the cultural dominance spectrum. We discuss the intensity (Fig. 5) and unpleasantness models (Fig. 6) in turn.

Among those endorsing greater Hispanic cultural dominance, the language context influenced reported pain intensity, and this relationship was significantly mediated by pain-evoked physiological arousal (indirect effect $ab = 0.027$, 95% CI [0.004, 0.060], $p = .030$). For these participants, the language condition significantly predicted pain-evoked arousal during heat stimulations (path $a = 0.086$, 95% CI [0.008, 0.164], $p = .030$; larger mSCRa during Spanish compared with English sessions), which in turn predicted higher pain intensity ratings (path $b = 0.311$, 95% CI [0.200, 0.422], $p = .015$). The strength of the direct relationship between physiological arousal and intensity ratings was weaker for Hispanic-dominant participants (path $b = 0.311$) compared with those endorsing greater US-American dominance (path $b = 0.470$; Fig. 5b). This difference was offset by a significant path a relationship between language condition and pain-evoked physiological arousal. The total effect of language context on pain intensity ratings ($c = 0.236$ [0.073, 0.420], $p = .008$) was significantly reduced after including the mediating role of mSCRa ($c' = 0.210$ [0.046, 0.370], $p = .012$). Thus, approximately 11.3% of the total effect (path c) of language on pain intensity was mediated by pain-evoked physiological arousal (path ab), based on the relative sizes of their path coefficients.

Among participants endorsing relatively higher US-American cultural identification, the significant total effect ($c = -0.209$, 95% CI [−0.389, −0.050], $p = .020$) of language on intensity ratings was slightly reduced by the inclusion of the mediation path ($c' = -0.180$, 95% CI, [−0.353, −0.030], $p = .026$). However, this drop did not represent a significant mediation of intensity ratings by pain-evoked physiological arousal (indirect effect $ab = -0.029$ [−0.070, 0.010], $p = .122$). Although larger mSCRa significantly predicted higher intensity ratings, controlling for language condition (path $b = 0.470$, 95% CI [0.348, 0.592], $p < .001$), the relative drop in physiological arousal from English to Spanish for these participants was not significant (path $a = -0.061$, 95% CI [−0.141, 0.018], $p = .129$). This direct path only non-mediation

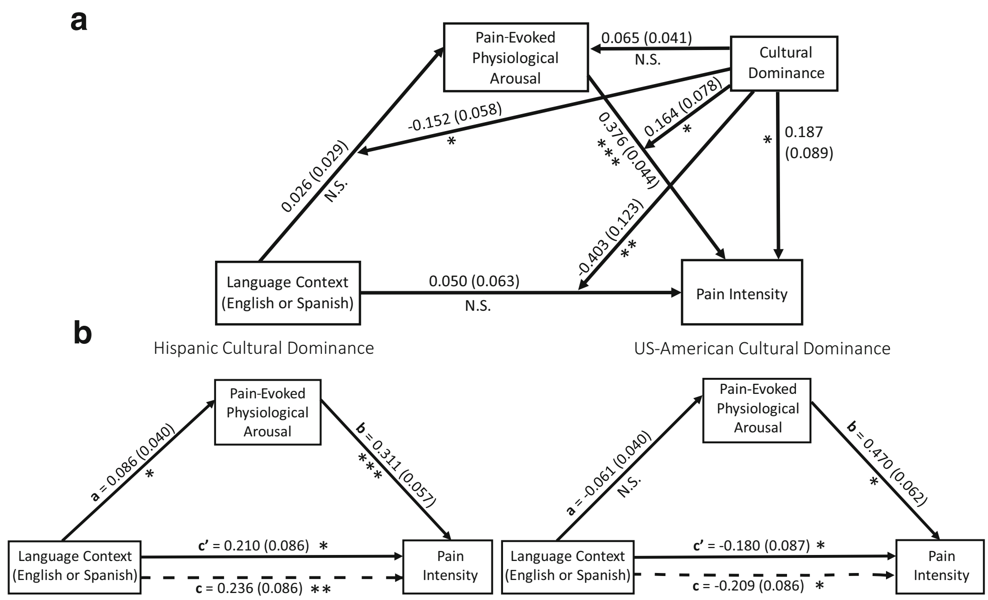

Fig. 5 Tested moderated mediation and conditional mediation models for pain intensity with path coefficients. **a** Full moderated mediation model for pain intensity ratings calculated from data of $N = 80$ bilingual participants with repeated measures across language sessions. **b** Path diagrams with coefficients of mediation relationships calculated with cultural dominance variable centered at − 1 standard deviation from the mean, Hispanic dominance (left), and + 1 standard deviation from the mean, US-American dominance (right). Language was coded as 0 for English and 1 for Spanish; thus, path coefficients from the "Language Context" box can be interpreted as the relative effect of the Spanish condition compared with English. Standard errors for each path coefficient are in parentheses. Dashed lines in **b** represent the total effect (*c* path) which can be compared with the solid *c*' path (direct effect). N.S., not significant. *$p < .05$, **$p < .01$, ***$p < .001$

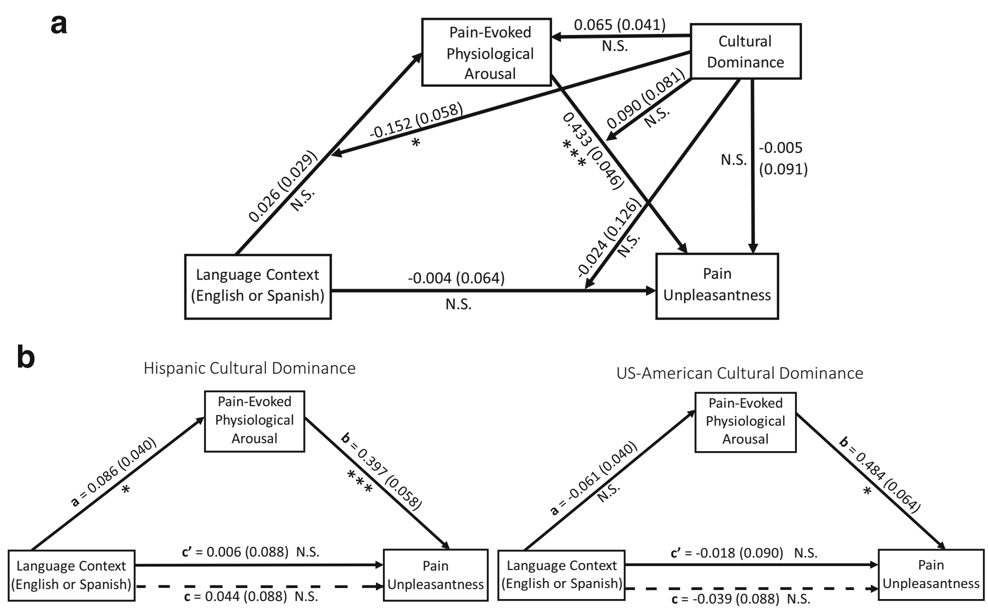

Fig. 6 Tested moderated mediation and conditional mediation models for pain unpleasantness with path coefficients. **a** Full moderated mediation model for pain unpleasantness ratings. **b** Path diagrams with coefficients of mediation relationships calculated with cultural dominance variable centered at − 1 standard deviation from the mean, Hispanic dominance (left), and + 1 standard deviation from the mean, US-American dominance (right). Language was coded as 0 for English and 1 for Spanish; thus, path coefficients from the "Language Context" box can be interpreted as the relative effect of the Spanish condition compared with English. Standard errors for each path coefficient are in parentheses. Dashed lines in **b** represent the total effect (*c* path) which can be compared with the solid *c*' path (direct effect). N.S., not significant. *$p < .05$, **$p < .01$, ***$p < .001$

relationship implies that other physiological or psychological mediators beyond mSCRa may be necessary (Zhao et al., 2010) to explain the relationship between language context and pain intensity for US-American-dominant participants.

As the language to pain intensity relationship ran in opposite directions depending on participants' cultural dominance, indirect (mediation) effects of similar magnitude were significantly different ($ab_{\text{Hisp}} - ab_{\text{US}} = 0.056$, 95% CI [0.009, 0.102], $p = .018$). Similarly, the direct effect of language on pain intensity ratings was larger for Hispanic-dominant compared with US-American-dominant participants ($c'_{\text{Hisp}} - c'_{\text{US}} = 0.390$, 95% CI [0.143, 0.628], $p = .001$). The inclusion of pain-evoked physiological arousal and additional cultural dominance interactions in the full moderated mediation model (Fig. 5a) resulted in a significant, main effect of cultural dominance on pain intensity ratings ($B = 0.187$, SE = 0.089, $p = .024$). However, we caution against strong interpretation of this main effect, given significant interactions including the cultural dominance variable.

In contrast to the pain intensity models, language did not produce a significant direct ($c'_{\text{Hisp}} = 0.006$, 95% CI [−0.145, 0.170], N.S.; $c'_{\text{US}} = -0.018$, 95% CI [−0.180, 0.160], N.S.) or total effect ($c_{\text{Hisp}} = -0.040$, 95% CI [−0.133, 0.210], N.S.; $c_{\text{US}} = -0.048$, 95% CI [−0.211, 0.140], N.S.) on pain unpleasantness ratings for either cultural dominance level. However, as with pain intensity, we found evidence for mediation of the language to pain unpleasantness relationship by pain-evoked physiological arousal for relatively Hispanic-dominant participants; we did not observe significant mediation effects for US-American-dominant participants. Specifically, Hispanic-dominant participants produced significantly larger mSCRa during Spanish compared with English sessions (path a = 0.086, 95% CI [0.008, 0.164], $p = .030$), while those endorsing greater US-American cultural dominance showed the opposite language to physiological arousal relationship, which did not reach significance (path $a = 0.061$, 95% CI [−0.141, 0.018], $p = .129$). For both groups, larger mSCRa was significantly predictive of higher pain unpleasantness ratings, with this relationship being slightly stronger among US-American-dominant (path $b = 0.484$, 95% CI [0.359, 0.609], $p < .001$) compared with Hispanic-dominant participants (path $b = 0.397$, 95% CI [0.282, 0.511], $p < .001$). Therefore, the indirect path from language context to pain unpleasantness mediated by pain-evoked arousal (mSCRa) was significant for Hispanic-dominant ($ab_{\text{Hisp}} = 0.034$, 95% CI [0.003, 0.070], $p = .048$) but not US-American-dominant participants ($ab_{\text{US}} = -0.030$, 95% CI [−0.071, 0.010], $p = .110$).

When comparing across these two models, we found a significantly greater meditation effect within the Hispanic-dominant compared with the US-American-dominant unpleasantness model ($ab_{\text{Hisp}} - ab_{\text{US}} = 0.064$, 95% CI [0.016, 0.121], $p = .007$). This result indicates that Hispanic-dominant participants' pain unpleasantness ratings were more sensitive to their pain-evoked physiological arousal than the unpleasantness ratings of US-American-dominant participants. However, the lack of total and direct effects, which showed no significant variation across cultural dominance levels ($c'_{\text{Hisp}} - c'_{\text{US}} = 0.024$, 95% CI [−0.214, 0.256], $p = .836$), implies that this mediation effect did not play a large role in determining participants' unpleasantness ratings. Figure 6 displays the overall moderated mediation model with path coefficients (a) as well as conditional mediation models at levels of relative Hispanic and US-American cultural dominance (b).

In total, pain-evoked physiological arousal significantly mediated the relationship between language context and pain ratings (both intensity and unpleasantness) for culturally Hispanic-dominant bilinguals. Pain intensity ratings were directly affected by language context for both culturally Hispanic- and US-American-dominant bilinguals, whereas language context did not directly affect pain unpleasantness ratings in either Hispanic or US-American models.

Discussion

Pain experiences are known to be modified by several social and cognitive processes (Czerniak et al., 2016; Koban & Wager, 2016; Narayan, 2010), but the role of language and culture in these relationships remains understudied. With this experiment, we observed that interplays between language and cultural identity meaningfully altered pain processing across bilingual Hispanics. Specifically, participants showed greater physiological arousal and reported higher pain intensity (but not unpleasantness) in the language of their dominant culture (e.g., Spanish for Hispanic-dominant participants). Pain-evoked physiological arousal significantly mediated the relationship between language context and pain ratings (both intensity and unpleasantness) particularly for Hispanic-dominant participants. Direct effects of language on pain intensity ratings for US-American-dominant participants were not mediated by physiological arousal.

The moderated mediation analyses suggest the mechanisms of explicit pain evaluation vary by cultural identification. As physiological arousal mediated 11.4% of the total effect of language on intensity ratings (indirect compared with total effect) for Hispanic-dominant participants, other untested physiological and psychological variables likely augment these language influences (Zhao et al., 2010). Despite non-significant total effects of language on pain unpleasantness, larger b compared with a path coefficients provided increased power to detect meditation (O'Rourke & MacKinnon, 2015) of this relationship by physiological arousal among Hispanic-dominant participants. This finding suggests that these participants experienced slightly higher pain unpleasantness in Spanish (compared with English), in line with findings of less emotional access in a second language (Wu & Thierry, 2012), though language effects on intensity ratings were appreciably stronger. Absence of significant mediation within US-American-dominant models implies other physiological (e.g., heart rate) or psychological (e.g., anxiety, familiarity) variables may explain these participants' direct language effects on pain intensity.

The lack of direct language effects on pain unpleasantness, like those seen for intensity ratings, may reflect the interaction of other psychological processes. As comfort can influence pain across conditions (see Czarnecki et al., 2011 for a review), pain unpleasantness (i.e., discomfort or distress) may have shown no direct language effects because participants felt more comfortable speaking their culturally preferred language. More intense pain may have been offset by general comfort in a given language, producing no overall unpleasantness change. Alternatively, reduced processing of negative emotional content in a second language, described in multiple bilingual event-related potential (ERP) studies (Jończyk et al., 2016; Jończyk et al., 2019; Wu & Thierry, 2012), may contribute to the non-significance of the language–unpleasantness relationship. As unpleasantness ratings are generally considered to tap the affective aspect of the pain experience (Auvray et al., 2010), reduced negative emotion in the less dominant language may make unpleasantness ratings more rationally determined, pushing them toward the middle of the scale. This reduced emotional access would contrast with more interoceptive and body-focused processing that could be driving language effects on intensity ratings and physiological responses (discussed below). Regardless of the mechanisms, we note that across various experimental and clinical settings, only pain intensity is evaluated (e.g., Mills et al., 2016; Tang & Gibson, 2005), meaning language-based changes in intensity may be of greater clinical relevance than unpleasantness changes.

Observed differences between Hispanic- and US-American-dominant participants imply that distinct processes may shape pain responses across these groups. Some evidence suggests that particularly late bilinguals show less embodied experiences in their second language (Pavlenko, 2012 for a review). Differential embodiment could lead bilingual participants to feel more bodily connection to stimulations in their dominant language, producing greater physiological arousal and subsequent pain assessments. Patterns of cognitive processing that vary across physical or social environments (i.e., "contextualized cognition"), frequently seen within collectivistic Hispanic cultures (Comas-Diaz, 2006), could further motivate Hispanic-dominant participants' sensitivity to the language manipulation (direct effects) and their bodily signals (mediation) when rating pain. US-American-identified participants, whose socioeconomic survey data show higher levels of education and personal and parental income, on average, compared with Hispanic-dominant participants, may have produced pain responses less sensitive to bodily arousal due to greater familiarity with the academic setting. Being more familiar with the experimental environment may then have reduced the influence of the language (cultural context) on these participants' implicit bodily responses. Some studies provide evidence that Hispanics may express greater mind–body integration compared with other ethnic groups (Canino et al., 1992), intermittently expressed as *ataques de nervios* (acute cognitive and physiological responses to distress) or frequent somatizing symptoms (Hulme, 1996). Thus, greater bodily awareness among Hispanic-identified bilinguals may explain the mediating role of physiological arousal in language–pain relationships and the lack of mediation among US-American-dominant participants.

Neither language effects on pain ratings nor physiological arousal emerged significantly for participants endorsing equivalent identification with US-American and Hispanic culture. While cultural identity and pain relationships are understudied, one experiment examined acculturation's influence on Hispanics' susceptibility to cultural priming. Contrary to our results, Chattaraman et al. (2010) found that "balanced biculturals'" preference for brands targeted at Hispanic or "mainstream" (i.e., US-American) consumers *were* influenced by viewing culturally salient priming images; conversely, "Hispanic-dominant" and "mainstream dominant" participants showed *no* priming effects. These results may stem from the underlying cultural salience of the stimuli. Recent work has suggested that sociocultural perspectives and contexts may shape interpretations of and responses to pain (Anderson & Losin, 2016; Hollingshead et al., 2016). Unlike preferences for brands targeting "mainstream" or "Hispanic-dominant" persons (Chattaraman et al., 2010), however, the stimulations evaluated in this study (i.e., a hot metal plate on the forearm) were not in themselves inherently cultural. While balanced biculturals shifted brand preferences because they resonated with both cultural identities, the stimulations' lack of explicitly cultural relevance may have meant that culturally balanced participants could perceive the associated pain similarly across languages.

By clarifying language–perception relationships, these results hold relevance for future experimental studies as well as documented pain assessment and treatment disparities among Hispanic populations. If our findings of lower pain ratings in English for Hispanic-dominant (Spanish preferring) individuals generalizes to English-speaking clinical contexts, this factor could be contributing to lower likelihood for Hispanics to receive analgesics (Anderson et al., 2009; Meghani et al., 2012) and less overall satisfaction with healthcare (Cersosimo & Musi, 2011), as their pain experience may not be fully communicated and subsequently incompletely addressed. While language concordant care can generally improve patient satisfaction and compliance (Ali & Johnson, 2017), our results indicate that cultural attitudes and identity can interact with language preferences and thus should be considered within clinical interactions. The fact that pain ratings exhibited stronger connections with physiological arousal for Hispanic-dominant participants suggests that this group may exhibit greater bodily awareness. This hypothesis could be tested in future studies which record metrics of interoceptive ability, known to relate to pain-evoked skin conductance measures (such as those in Cameron, 2001), across culturally defined bilingual samples. This study highlights that Hispanic populations are not monolithic in their pain evaluation; while seeking to address language barriers in healthcare (Segalowitz & Kehayia, 2011), we note that switching languages may produce different results based on patients' cultural associations and identity.

These results must be qualified by certain limitations. First, our sample comprised a limited range of cultural dominance scores, with more participants endorsing US-American dominance. These participants' lower spread in dominance scores suggests the tested mediation could become significant among bilinguals with US-American dominance higher than our sample contained. Further, cultural dominance was a broad measure of cultural identification and did not include particular cultural values (e.g., *machismo*, *personalismo*; Comas-Diaz, 2006) that could also contribute to language effects. This composite measure may not represent a unitary construct and requires a larger sample to describe its underlying factor structure (Mundfrom et al., 2005). While controlling age of second language acquisition experimentally and frequency of language use via cultural dominance, language effects could have reflected participants' daily or historical language use. Despite the temporal precedence of mSCRa to pain ratings, it remains possible that participants thought of their upcoming rating during the heat, in turn altering their physiological arousal. We find this inverse interpretation less plausible, but nonetheless cannot rule it out with the present analyses. These limitations do not prevent reasonable confidence in this study's observed language and cultural identity effects on pain processing.

Conclusion

We provide empirical evidence that language and cultural identity can interact to alter pain experiences among bilingual Hispanics/Latinos. Study participants showed higher physiological arousal and reported more intense pain in the language of their dominant culture. The relationship between language and pain ratings was mediated by physiological arousal for culturally Hispanic-dominant participants. These finding hold relevance in understanding how language and culture shape perceptual processes and could ultimately be applied to help mitigate disparities in pain treatment and healthcare satisfaction among Hispanic/Latino populations.

Additional Information

Supplementary Information The online version of this article (https://doi.org/10.1007/s42761-020-00021-x) contains supplementary material, which is available to authorized users.

Acknowledgments The authors wish to thank Sofia Mercer, Beatriz Yepes, Efrain Rodriguez Sierra, and Felipe Parodi for their contributions to this research project. Without their efforts the collection of these data would not have been possible.

Author Contributions EL and ML provided guidance in the design of the experimental paradigm and significant input in the data analysis process. MG conducted the experimental procedure, compiled and analyzed the data, and wrote the manuscript with input and revision from EL and ML.

Funding This research was supported by startup funds of Dr. Elizabeth Losin from the University of Miami.

Availability of Data and Materials All data from this project will be made available on the Open Science Framework (OSF) by the end of 2020 (https://osf.io/5tw79/?view_only=d113177c1f244758a4361bca58de7802).

Conflict of Interest The authors declare that they have no conflicts of interest.

Code Availability All R codes will be made available on OSF (same link as above).

Ethical Approval All procedures were approved by the University of Miami Institutional Review Board (Protocol #20180105).

Informed Consent Informed consent was obtained from all participants after a detailed study explanation in both English and Spanish.

References

Ali, P. A., & Johnson, S. (2017). Speaking my patient's language: Bilingual nurses' perspective about provision of language concordant care to patients with limited English proficiency. *Journal of Advanced Nursing, 73*(2), 421–432.

Anderson, K. O., Green, C. R., & Payne, R. (2009). Racial and ethnic disparities in pain: Causes and consequences of unequal care. *The Journal of Pain, 10*(12), 1187–1204. https://doi.org/10.1016/j.jpain.2009.10.002.

Anderson, S. R., & Losin, E. A. R. (2016). A sociocultural neuroscience approach to pain. *Culture and Brain, 5*(1), 14–35. https://doi.org/10.1007/s40167-016-0037-4.

Aslaksen, P., Myrbakk, I., Høifødt, R., & Flaten, M. (2007). The effect of experimenter gender on autonomic and subjective responses to pain stimuli. *Pain, 129*, 260–268. https://doi.org/10.1016/j.pain.2006.10.011.

Auvray, M., Myin, E., & Spence, C. (2010). The sensory-discriminative and affective-motivational aspects of pain. *Neuroscience & Biobehavioral Reviews, 34*(2), 214–223.

Bates, D., Machler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using "lme4". *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01.

Benedek, M., & Kaernbach, C. (2010). A continuous measure of phasic electrodermal activity. *Journal of Neuroscience Methods, 190*(1), 80–91.

Bollen, K. A., & Jackman, R. W. (1985). Regression diagnostics an expository treatment of outliers and influential cases. *Sociological Methods & Research, 13*(4), 510–542.

Breivik, H., Borchgrevink, P. C., Allen, S. M., Rosseland, L. A., Romundstad, L., Breivik Hals, E. K., Kvarstein, G., & Stubhaug, A. (2008). Assessment of pain. *BJA: British Journal of Anaesthesia, 101*(1), 17–24. https://doi.org/10.1093/bja/aen103.

Cameron, O. G. (2001). Interoception: The inside story—a model for psychosomatic processes. *Psychosomatic Medicine, 63*(5), 697–710.

Campbell, C. M., & Edwards, R. R. (2012). Ethnic differences in pain and pain management. *Pain Management, 2*(3), 219–230.

Canino, I. A., Rubio-Stipec, M., Canino, G., & Escobar, J. I. (1992). Functional somatic symptoms: A cross-ethnic comparison. *American Journal of Orthopsychiatry, 62*(4), 605–612.

Cersosimo, E., & Musi, N. (2011). Improving treatment in Hispanic/Latino patients. *The American Journal of Medicine, 124*(10), S16–S21.

Chattaraman, V., Lennon, S. J., & Rudd, N. A. (2010). Social identity salience: Effects on identity-based brand choices of Hispanic consumers. *Psychology & Marketing, 27*(3), 263–284. https://doi.org/10.1002/mar.20331.

Chiao, J. Y., Harada, T., Komeda, H., Li, Z., Mano, Y., Saito, D., Parrish, T. B., Sadato, N., & Iidaka, T. (2010). Dynamic cultural influences on neural representations of the self. *Journal of Cognitive Neuroscience, 22*(1), 1–11. https://doi.org/10.1162/jocn.2009.21192.

Comas-Diaz, L. (2006). Latino healing: The integration of ethnic psychology into psychotherapy. *Psychotherapy: Theory, Research, Practice, Training, 43*(4), 436.

Critchley, H. D., & Garfinkel, S. N. (2017). Interoception and emotion. *Current Opinion in Psychology, 17*, 7–14.

Czarnecki, M. L., Turner, H. N., Collins, P. M., Doellman, D., Wrona, S., & Reynolds, J. (2011). Procedural pain management: A position statement with clinical practice recommendations. *Pain Management Nursing, 12*(2), 95–111.

Czerniak, E., Biegon, A., Ziv, A., Karnieli-Miller, O., Weiser, M., Alon, U., & Citron, A. (2016). Manipulating the placebo response in experimental pain by altering doctor's performance style. *Frontiers in Psychology, 7*, 874.

Edwards, R. R., & Fillingim, R. B. (1999). Ethnic differences in thermal pain responses. *Psychosomatic Medicine, 61*(3), 346–354.

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments, & Computers, 28*(1), 1–11.

Everett, C. (2013). *Linguistic relativity: evidence across languages and cognitive domains*. Publisher: De Gruyter Mouton. https://doi.org/10.1515/9783110308143.

Fausey, C. M., & Boroditsky, L. (2011). Who dunnit? Cross-linguistic differences in eye-witness memory. *Psychonomic Bulletin & Review, 18*(1), 150–157.

Guttfreund, D. G. (1990). Effects of language usage on the emotional experience of Spanish-English and English-Spanish bilinguals. *Journal of Consulting and Clinical Psychology, 58*(5), 604–607.

Hjermstad, M. J., Fayers, P. M., Haugen, D. F., Caraceni, A., Hanks, G. W., Loge, J. H., et al. (2011). Studies comparing numerical rating scales, verbal rating scales, and visual analogue scales for assessment of pain intensity in adults: A systematic literature review. *Journal of Pain and Symptom Management, 41*(6), 1073–1093.

Hollingshead, N. A., Ashburn-Nardo, L., Stewart, J. C., & Hirsh, A. T. (2016). The pain experience of Hispanic Americans: A critical literature review and conceptual model. *The Journal of Pain, 17*(5), 513–528.

Hulme, P. A. (1996). Somatization in Hispanics. *Journal of Psychosocial Nursing and Mental Health Services, 34*(3), 33–37.

Ingoldsby, B. B. (1991). The Latin American family: Familism vs. machismo. *Journal of Comparative Family Studies, 22*(1), 57–62.

Jensen, M. P., Turner, J. A., Romano, J. M., & Karoly, P. (1991). Coping with chronic pain: A critical review of the literature. *Pain, 47*(3), 249–283.

Jepma, M., Jones, M., & Wager, T. D. (2014). The dynamics of pain: Evidence for simultaneous site-specific habituation and site-nonspecific sensitization in thermal pain. *The Journal of Pain, 15*(7), 734–746. https://doi.org/10.1016/j.jpain.2014.02.010.

Jończyk, R., Boutonnet, B., Musiał, K., Hoemann, K., & Thierry, G. (2016). The bilingual brain turns a blind eye to negative statements in the second language. *Cognitive, Affective, & Behavioral Neuroscience, 16*(3), 527–540.

Jończyk, R., Korolczuk, I., Balatsou, E., & Thierry, G. (2019). Keep calm and carry on: Electrophysiological evaluation of emotional anticipation in the second language. *Social Cognitive and Affective Neuroscience, 14*(8), 885–898.

Koban, L., & Wager, T. D. (2016). Beyond conformity: Social influences on pain reports and physiology. *Emotion, 16*(1), 24–32. https://doi.org/10.1037/emo0000087.

Lautenbacher, S., Peters, J. H., Heesen, M., Scheel, J., & Kunz, M. (2017). Age changes in pain perception: A systematic-review and meta-analysis of age effects on pain and tolerance thresholds. *Neuroscience & Biobehavioral Reviews, 75*, 104–113.

Lechuga, J. (2008). Is acculturation a dynamic construct? The influence of method of priming culture on acculturation. *Hispanic Journal of Behavioral Sciences, 30*(3), 324–339. https://doi.org/10.1177/0739986308319570.

Legrain, V., Van Damme, S., Eccleston, C., Davis, K. D., Seminowicz, D. A., & Crombez, G. (2009). A neurocognitive model of attention to pain: Behavioral and neuroimaging evidence. *Pain, 144*(3), 230–232.

Levine, F. M., & De Simone, L. L. (1991). The effects of experimenter gender on pain report in male and female subjects. *Pain, 44*(1), 69–72.

Luk, G., De Sa, E., & 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.

Lynch, A. (2009). A sociolinguistic analysis of final/s/in Miami Cuban Spanish. *Language Sciences, 31*(6), 766–790.

Meghani, S. H., Byun, E., & Gallagher, R. M. (2012). Time to take stock: A meta-analysis and systematic review of analgesic treatment disparities for pain in the United States. *Pain Medicine, 13*(2), 150–174.

Mills, S., Torrance, N., & Smith, B. H. (2016). Identification and management of chronic pain in primary care: A review. *Current Psychiatry Reports, 18*(2), 22.

Morris, M. W., & Mok, A. (2011). Isolating effects of cultural schemas: Cultural priming shifts Asian-Americans' biases in social description and memory. *Journal of Experimental Social Psychology, 47*(1), 117–126. https://doi.org/10.1016/j.jesp.2010.08.019.

Mundfrom, D. J., Shaw, D. G., & Ke, T. L. (2005). Minimum sample size recommendations for conducting factor analyses. *International Journal of Testing, 5*(2), 159–168.

Narayan, M. C. (2010). Culture's effects on pain assessment and management. *AJN The American Journal of Nursing, 110*(4), 38–47.

Ng, S. H., Han, S., Mao, L., & Lai, J. C. (2010). Dynamic bicultural brains: fMRI study of their flexible neural representation of self and significant others in response to culture primes. *Asian Journal of Social Psychology, 13*(2), 83–91. https://doi.org/10.1111/j.1467-839X.2010.01303.x.

O'Rourke, H. P., & MacKinnon, D. P. (2015). When the test of mediation is more powerful than the test of the total effect. *Behavior Research Methods, 47*(2), 424–442.

Ostrom, C., Bair, E., Maixner, W., Dubner, R., Fillingim, R. B., Ohrbach, R., Slade, G. D., & Greenspan, J. D. (2017). Demographic predictors of pain sensitivity: Results from the OPPERA study. *The Journal of Pain, 18*(3), 295–307.

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

Preacher, K. J., Rucker, D. D., & Hayes, A. F. (2007). Addressing moderated mediation hypotheses: Theory, methods, and prescriptions. *Multivariate Behavioral Research, 42*(1), 185–227.

Prieto, A. J. (1992). A method for translation of instruments to other languages. *Adult Education Quarterly, 43*(1), 1–14.

R Core Team. (2019). A language and environment for statistical computing. *R Foundation for Statistical Computing*. Vienna, Austria. https://www.R-project.org/.

Rahim-Williams, F. B., Riley III, J. L., Herrera, D., Campbell, C. M., Hastie, B. A., & Fillingim, R. B. (2007). Ethnic identity predicts experimental pain sensitivity in African Americans and Hispanics. *Pain, 129*(1–2), 177–184.

Ramírez-Esparza, N., Gosling, S. D., Benet-Martínez, V., Potter, J. P., & Pennebaker, J. W. (2006). Do bilinguals have two personalities? A special case of cultural frame switching. *Journal of Research in Personality, 40*(2), 99–120.

Reicherts, P., Gerdes, A. B., Pauli, P., & Wieser, M. J. (2016). Psychological placebo and nocebo effects on pain rely on expectation and previous experience. *The Journal of Pain, 17*(2), 203–214.

Riley 3rd, J. L., King, C. D., Wong, F., Fillingim, R. B., & Mauderli, A. P. (2010). Lack of endogenous modulation and reduced decay of prolonged heat pain in older adults. *Pain, 150*(1), 153–160.

Rosseel, Y. (2012). "lavaan": An R package for structural equation modeling. *Journal of Statistical Software, 48*(2), 1–36.

Ružić, V., Ivanec, D., & Stanke, K. M. (2017). Effect of expectation on pain assessment of lower-and higher-intensity stimuli. *Scandinavian Journal of Pain, 14*, 9–14.

Schonberg, C. C., Russell, E. E., & Luna, M. (2019). Effects of past language experience and present language context on the shape bias in Spanish-English bilingual children. *Developmental Science*, e12879. https://doi.org/10.1111/desc.12879.

Schulz, P. J., Hartung, U., & Riva, S. (2013). Causes, coping, and culture: A comparative survey study on representation of back pain in three Swiss language regions. *PLoS One, 8*(11), e78029.

Segalowitz, N., & Kehayia, E. (2011). Exploring the determinants of language barriers in health care (LBHC): Toward a research agenda for the language sciences. *The Canadian Modern Language Review, 67*(4), 480–507.

Sorlie, P. D., Avilés-Santa, L. M., Wassertheil-Smoller, S., Kaplan, R. C., Daviglus, M. L., Giachello, A. L., et al. (2010). Design and implementation of the Hispanic community health study/study of Latinos. *Annals of Epidemiology, 20*(8), 629–641.

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2013). *Using multivariate statistics* (Vol. 6). Boston, MA: Pearson.

Tang, J., & Gibson, S. J. (2005). A psychophysical evaluation of the relationship between trait anxiety, pain perception, and induced state anxiety. *The Journal of Pain, 6*(9), 612–619.

Taylor, P., Lopez, M. H., Martínez, J. H., & Velasco, G. (2012). *When labels don't fit: Hispanics and their views of identity*. Washington, DC: Pew Hispanic Center.

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., & Imai, K. (2014). Mediation: R package for causal mediation analysis. *Journal of Statistical Software, 59*(5). https://doi.org/10.18637/jss.v059.i05.

U.S. Census Bureau. (2017). *Profile America facts for features: Hispanic heritage month 2017*. Release Number CB17-FF.17. URL: https://www.census.gov/content/dam/Census/newsroom/facts-for-features/2017/cb17-ff17.pdf.

Woo, C.-W., Roy, M., Buhle, J. T., & Wager, T. D. (2015). Distinct brain systems mediate the effects of nociceptive input and self-regulation on pain. *PLoS Biology, 13*(1), e1002036. https://doi.org/10.1371/journal.pbio.1002036.

Wu, Y. J., & Thierry, G. (2012). How reading in a second language protects your heart. *Journal of Neuroscience, 32*(19), 6485–6489.

Zea, M. C., Asner-Self, K. K., Birman, D., & Buki, L. P. (2003). The Abbreviated Multidimentional Acculturation Scale: Empirical validation with two Latino/Latina samples. *Cultural Diversity and Ethnic Minority Psychology, 9*(2), 107–126.

Zhao, X., Lynch Jr., J. G., & Chen, Q. (2010). Reconsidering Baron and Kenny: Myths and truths about mediation analysis. *Journal of Consumer Research, 37*(2), 197–206.

Zuur, A. F., Ieno, E. N., & Elphick, C. S. (2010). A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution, 1*(1), 3–14.