Social Networks as a Measure of Bilingual Language Experience

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Abstract

Although nearly half of the global population is bilingual, understanding how social context shapes language use and proficiency remains a fundamental challenge in language science. Traditional measures of bilingual experience rely on generalized language history questionnaires that fail to capture the interpersonal dynamics and contextual variation characterizing everyday multilingual communication. Current theories propose that bilingual language control adapts to different communicative contexts, but existing methodologies cannot adequately assess how bilinguals compartmentalize or integrate their languages across interactive relationships. This study addresses whether personal network analysis can reveal unique insights into bilingual language experience that point to potential factors for heritage language maintenance. Here we show that social network composition significantly predicts heritage language proficiency outcomes in ways that generalized questionnaires fail to capture. Personal network analysis of 38 Spanish-English heritage bilinguals revealed substantial interpersonal variation in language use patterns, including monolingual English use in reportedly Spanish-dominant contexts. The proportion of Spanish-only interactions within participants' social networks predicted verbal fluency performance, picture naming accuracy, and response times, with stronger effects for low-frequency vocabulary access. These findings support the pressing need for measures that capture sociolinguistic dynamics of interpersonal language use to better understand heritage bilingual language experiences. Our results evidence that interpersonal network dynamics fundamentally shape bilingual language processing and proficiency outcomes. This approach offers language scientists a methodological framework for capturing the inherently social nature of bilingual language experience, with implications for understanding heritage language maintenance across multilingual communities worldwide.
Key words: Spanish-English bilingual experience, heritage language maintenance, personal social networks

Social Networks as a Measure of Bilingual Language Experience

Perspectives on bilingualism have dramatically evolved throughout the past century as research has sought to understand the inner workings of language experience. Bilinguals' differential performance on linguistic tasks revealed increased cognitive demands for bilingual language use, leading researchers to the widely accepted theory that bilinguals' languages are active in parallel, perpetually competing for attentional resources (Bialystok, 2010). The Inhibitory Control model posits that in order to regulate and control language use, bilinguals must selectively attend to one language system, suppressing the other (Green, 1998). More recently, the Adaptive Control model (Green & Abutalebi, 2013) proposed that linguistic control processes configure and adapt to meet the demands of different communicative contexts. For instance, when a Spanish-English bilingual speaks to monolingual Spanish speakers, Spanish is the 'target' language; any representations from non-target languages (i.e., English) need to be inhibited. This leads to the question: How does language control manifest when two Spanish-English bilinguals speak to each other?

Increased recognition of the dynamic, complex nature of bilingualism has led researchers to question whether a purely competitive language control model can effectively encompass the diversity of bilingual language experiences and behaviors. Codeswitching, a phenomenon in which bilinguals blend multiple languages within a single interaction, sentence or utterance (Poplack, 1980), reveals limitations of the Inhibitory Control model. Codeswitching behaviors outline a cooperative mode of language control that enables the integrated use of dual language systems (Green & Wei, 2014). Given the demands of communicative context vary depending on which languages are recurrently present in conversation, language competition is maximized in single-language contexts (e.g., using only Spanish with family and only English at work), suppressing the non-target language to ensure only the contextually correct language is used. In contrast, bilinguals in dense codeswitching contexts rely on

cooperative language control to integrate resources from both languages, which may be an opportunistic strategy for communicative precision between bilinguals (Beatty-Martínez et al., 2020a). This demonstrates how differential linguistic conventions and interpersonal dynamics across social networks shape systemic variation in bilingual behavior and language experiences. If one freely codeswitches with some groups of communicative partners while sticking with single-language norms with other groups, social network composition should predict whether language control processes lean towards a competitive or cooperative model.

Bilinguals from similar language environments may have critically differential patterns of language use as a result of linguistic and interpersonal variation between and within the interactional contexts they recurrently engage in. For example, two bilingual speakers from the same population who both report using each language 50% of the time may appear to have similar language experiences; however without social context, such uniform reports can mask drastically different patterns of interpersonal language use (see Fig. 1). Although both bilinguals report balanced language use, differential linguistic demands and interpersonal dynamics of their social networks give rise to paths of adaptive change in language processes – while bilinguals in heterogeneous networks are adept at exploiting competitive language control to selectively use one language at a time, those in homogeneous networks excel at integrating their languages due to extensive codeswitching experience (Beatty-Martínez & Titone, 2021). This illustrates that there is no 'universal' pattern of bilingual language experience – rather, the

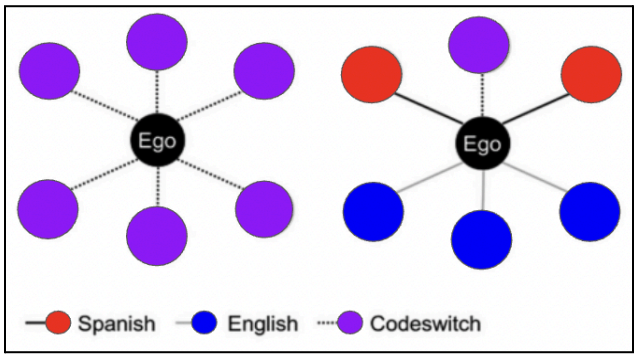

Figure 1. Hypothetical social networks of self-reported 50/50 Spanish-English bilinguals in distinct interactional contexts. Left: A linguistically homogeneous network with codeswitching between all individuals. Right: A linguistically heterogeneous network with varied dynamics that constrain language use.

unique interpersonal dynamics that constitute each bilingual's personal network shape language processes. The majority of past research relies on generalized measures of language experience (e.g., language history questionnaires) that fail to evaluate interpersonal dynamics of language use. In attempting to control for variation across samples and conditions, past methodologies fail to assess the degree to which bilinguals compartmentalize or integrate their languages across interactive contexts – a crucial mediator of adaptive change in language processing (Beatty-Martínez & Titone, 2021). Shaped by sociolinguistic context, bilingual language experiences fundamentally alter the structure and function of the mind (Kroll & Bialystok, 2013). Therefore, language science needs methodologies capable of capturing interpersonal sociolinguistic dynamics in order to adequately address the adaptive, experience-based, contextually-dependent nature of bilingual language experience.

This insight is particularly relevant when studying Spanish-English bilingualism in the U.S. – a linguistically diverse yet English-dominant environment where Spanish is the most common minority language, with over 40 million citizens estimated to speak Spanish in the home (Census Bureau, 2023). California hosts the largest Latino population in the United States (40% of residents; Korhonen, 2024), with a significant subset being heritage bilinguals who learned Spanish in the home setting, typically while engaging with English in more formal environments (US Census Bureau, 2021; Lynch, 2003). Research from the Pew Research Center (2021) illuminates this complexity, revealing that while over 90% of US-born Hispanics are proficient in English, most have limited formal Spanish education, contributing to the challenges in maintaining language abilities across generations. By the third generation, two-thirds of Latinos cannot carry a conversation well in Spanish (Mora & Lopez, 2023), underscoring the critical need to understand the systematic variation of heritage bilingual experiences in communities like San Diego. These intergenerational patterns of language loss reflect the complex interplay between individual cognition and social environment, underscoring

the pressing need to understand how bilingual experiences contribute to heritage language maintenance. However, adequate measures for characterizing bilingual language experiences still pose a significant challenge. This underscores the importance of asking: how does bilingual language experience shape heritage language maintenance across different individuals and contexts?

As traditional language history questionnaires fall short in addressing questions related to interpersonal dynamics of everyday bilingual interaction, this study proposes leveraging personal network analysis as a more contextually sensitive measure of bilingual experience. Personal network analysis is an approach to operationalizing social context by mapping social environments and analyzing variation to investigate the effects of social context. As shown in Figure 1, networks consist of “nodes” (i.e., agents in the network) and the “edges” or ties between them. Personal networks can be used to investigate respondents’ (i.e., “egos”) social systems and their network members (i.e., “alters”) in order to assess the effect of interpersonal relationships on an individual (McCarty et al, 2019). Egocentric personal network analysis provides a powerful, contextualized measurement of bilingual language experience that circumvents the shortcomings of traditional, overgeneralized approaches. For instance, Figure 1 illustrates how bilinguals who report identical proportions of language use on generalized measures can display distinct patterns of language use due to differences in their social networks (Beatty-Martínez et al., 2024). This network science approach can differentiate between egos based on alter characteristics, providing insights into how interactional context mediates language use. For example, the significantly higher proportion of bilingual alters in the first ego’s network (Fig. 1, left) enables more cooperative language use, while the second ego (Fig. 1, right) must maximize language competition to effectively communicate with their monolingual alters. Outside of language abilities, personal network analysis enables us to assess both individual and interpersonal variables such as alter demographics and ego-alter

relationship attributes (e.g., emotional closeness), that may uncover nuanced patterns of language use that traditional approaches might miss. Furthermore, interpersonal dynamics and patterns of language use revealed by personal network analysis can then be related to measures of objective language proficiency to better understand correlates of heritage language maintenance. Personal network models can provide detailed, impactful representations of how interpersonal relationships and context-specific sociolinguistic demands may shape bilingual language experiences.

Considering that traditional measures of language experience (i.e., language history questionnaires) fail to gather sociolinguistic data at the interpersonal level, will a personal network approach reveal insights into Spanish-English heritage bilingual language experiences that generalized measures alone cannot? Furthermore, given the influence of sociolinguistic experiences on language processing, do interactional patterns of bilingual language use relate to objective proficiency outcomes in the heritage language (i.e., Spanish)? In order to circumvent the limits of traditional methodology, the present study utilizes a novel personal network measure to investigate the relationship between interpersonal patterns of language use and heritage bilingual language experiences. I hypothesize that personal network analysis will reveal contextualized insights into bilingual language experiences that a language history questionnaire alone cannot. In addition, I predict that observed patterns of bilingual language use will correlate with objective proficiency outcomes. Specifically, I expect higher proportions of Spanish-only ego-alter language use per social network to correspond with higher scores on measures of objective Spanish proficiency, as more frequent Spanish interactions likely provide the sustained practice necessary for heritage language maintenance. Not only will this personal network approach address a gap in the literature, but it will also provide a novel perspective on the dynamics of bilingual language use that transcends cognition without context. Analyzing the dynamics of social networks will quantitatively characterize the inherently interpersonal nature of

language use, leading to a more comprehensive understanding of how social patterns of language use impact heritage language maintenance. Furthermore, this study will contribute to our understanding of the dynamic sociolinguistic experiences of Spanish heritage speakers in San Diego, which may inform approaches to preserving heritage language use across generations.

Methods

Participants

Thirty-eight Spanish-English heritage bilinguals (81.58% female, Mean age = 19.68 years, SD = 1.95) were recruited from the University of California, San Diego, using the Psychology Department's participant pool management software (Sona Systems; https://www.sona-systems.com). While some were born in Mexico (15.79%, n = 6), the majority of participants (84.2%) were born in the United States (n = 32). Mexican-born participants originated from Baja California (n = 3), Jalisco (n = 1), and Coalinga (n = 1), while the vast majority of US-born participants were from California (n = 31), with one born in Idaho (n = 1).

Eligibility criteria were as follows: at least 18 years old, learned Spanish in the home setting, learned English relatively early on (i.e., in the home or at school), normal or corrected-to-normal vision and no history of hearing loss, neurological, psychiatric or language disorders. Course credit was offered as an incentive for participation. Before taking part in the study, all participants were informed of any potential risks and the voluntary nature of participation before choosing whether to consent to the study. All participants gave their informed consent in accordance with the protocols approved by the University of California, San Diego Human Research Protections Program.

Materials and Procedure

Data were collected in two sessions: the first via two online questionnaires and the second through objective language proficiency tasks in the laboratory. These materials received Institutional Review Board (IRB) approval from the University of California, San Diego.

Online Questionnaires

In Part 1 of the study, participants completed customized language history and personal network questionnaires online while monitored on Zoom to ensure their focus and ability to ask clarifying questions if needed.

Language History Questionnaire (LHQ). The Language History Questionnaire was administered using Qualtrics (https://www.qualtrics.com) and consists of 6 major sections: demographics, language history, contexts of language use, codeswitching, heritage, and classroom experience, which are detailed below.

The demographics section asks about participants' birthplace (country and state/municipality/province), education (of participants and their primary caregivers) and socioeconomic status. Subsequently, the language history portion of the LHQ inquires about language(s) spoken by participants' primary caregivers in general and in the home growing up, ranked in order of most to least commonly used. Participants then report which language(s) they currently use, have learned or are learning and rate their level of proficiency in speaking, writing, reading and understanding each language. Then, respondents rank their language speaking preferences, report their age of acquisition per language and estimate the number of years they have spent in environments where their spoken languages were the minority or majority.

The contexts of language use section first asks participants to estimate what percentage of the time they use each of their languages in a typical week. Respondents then specify which interactional contexts they engage in on a weekly basis (options are school, work, social, family household [i.e., immediate family] and extended family) and estimate the percentage of waking hours spent in each context in an average week. Next, respondents report which languages

they use in each context (i.e., Spanish only, English only or both) and identify which language(s) they use for certain activities (e.g., watching TV/movies, listening to music, reading books, watching/reading the news and social media).

The codeswitching block of the LHQ first defines codeswitching as “using two or more languages in the same conversation when talking with someone else”, then asks respondents if they ever switch between multiple languages in the same conversation. If participants respond “yes” or “maybe”, they subsequently assess how frequently they codeswitch in general, the degree to which they use English words dispersedly throughout their Spanish sentences and the degree to which they switch languages between and within sentences (on a 1 to 9 scale from never to always). Participants indicate how frequently they typically codeswitch in each interactional context then for each selected context, estimate the degree to which they use more than one language and the degree to which their switching habits depend on the person they’re interacting with (on a 1 to 9 scale from never to always). Participants assess why they think they codeswitch, with responses being: “because I don't remember a word in the other language”, “because I don't know a word in the other language”, “because I feel like it”, “habitual experience”, “to add emphasis”, “to avoid misunderstanding”, “to exclude other people”, “to address a different speaker”, “to show identity with a group” and “to express something more adequately”. Finally, respondents note which language they typically start and finish a sentence in when codeswitching.

The heritage portion of the LHQ asks if participants’ parents were born and raised in the same country as them. If respondents answer no, they then specify which country their mother and father were born in and indicate whether they traveled to their parents’ countries of origin. If they do so, participants note how often they travel to their heritage countries and their average length of stay in each heritage country.

Lastly, the classroom learning block has participants select where they began learning each language (outside an educational setting, during primary education, during secondary education or higher education). Participants note whether they are currently enrolled in any language courses and indicate the highest level of university language course taken per language, if applicable. Subsequently, respondents indicate whether they had any formal education in their heritage language (i.e., Spanish). If they have, participants then select which language education program(s) they went to: integrated English as a Second Language (ESL) (where bilingual students remain with the rest of their class), pull-out/standalone ESL (where bilingual students spend a portion of their day in a separate ESL class), dual language immersion, transitional bilingual education, and other (specified).

Personal Network Survey (PNS). The Personal Network Survey is a custom network science measure created and administered using Network Canvas Fresco (Complex Data Collective, 2016) in which bilingual participants detail their language use and interpersonal relationships within their social network. Upon beginning the survey, participants are informed that they will be asked to answer questions about people with whom they regularly interact across various areas of everyday life, with the questionnaire defining “interaction” as “any form of meaningful communication, such as in-person conversations, voice or video calls, instant messages, or text-based engagement on social media (e.g. commenting on or responding to posts).”

Next, participants list 15 people (“alters”) they have interacted with regularly over the past year across various aspects of life (e.g., work, school, family) and subsequently sort each alter into the following age groups: “under 10”, “10-17”, “18-25”, “26-35”, “36-45”, “46-55”, “56-65” and “over 65”. Respondents then sort alters based on closeness, which is defined as “how personally connected you feel to someone, how comfortable you are sharing personal feelings or being supported by them emotionally. Categories for closeness are: “not close at all”

(you know their name and occasionally say hi but don't interact much), "somewhat close" (you have casual conversations but don't share personal details or rely on them for support), "moderately close" (you talk often and share some personal experiences but don't seek them out for emotional support), "pretty close" (you confide in them, share feelings, and trust them to support you) and "extremely close" (you share secrets and rely on them as a primary source of emotional support).

Respondents subsequently sort alters based on their frequency of contact with that person, with options being: "at least once a year", "at least once every few months", "at least once a month", "at least once a week" and "at least once a day". Then, participants categorize alters based on what context they most frequently or significantly interact with each person in. Social context categories are: family household (people you live with, e.g., parents, siblings, spouse), extended family (relatives, close friends you consider part of your family, not living together), community (non-relatives that you share living spaces with, such as housemates or neighbors), school (classmates, professors), work (coworkers, supervisors, or clients), and social (people you primarily interact with in recreational contexts outside of school or work). After that, participants sort people in their network by gender, with categories being "male", "female" and "other".

Participants then select which modes of communication they have used to interact with each alter over the past year, with options being: "in-person" (face-to-face communication, not online), "professional calls" (Zoom, Microsoft Teams, other video/voice-based platforms for professional or academic settings), "professional text messaging" (Slack, email, other text-based platforms used in professional or work-related settings), "casual calls" (phone calls, FaceTime, and other video/voice-based platforms used for communication in non-professional settings), "casual instant messaging" (Snapchat, WeChat, WhatsApp, other real-time, text-based communication through personal messaging apps), and "social media" (Instagram, Facebook,

and other social media platforms where you comment on photos, reply to stories, or post updates). In this same question, participants also report which city/town each alter currently lives in, or if they do not know, which state/province or country.

Subsequently, participants indicate which languages each alter generally uses, then specify which languages they use with each alter in general. Based on the most prevalent languages in San Diego (County of San Diego, 2017), response choices are: English, Spanish, Mandarin, Cantonese, Vietnamese, Korean, Filipino/Tagalog, French, Japanese and Other. Following that, participants are asked about codeswitching frequency: how often they have switched between two or more languages or dialects during interactions with each bilingual alter over the past year. Respondents only answer this question about alters they reported using more than one language with, so answer choices are: “rarely” (you occasionally switch languages but mostly stick to one language), “sometimes” (you switch languages in about half of your interactions), often (you frequently switch between languages during most interactions) and “always” (you consistently use more than one language during all interactions). Finally, participants create a comprehensive list of connections (i.e., “ties” or “edges”) between alters within their network, with ties being determined by whether two alters interact with each other independently of the participant. To ensure no connections are missed, participants are asked about all possible combinations of alters.

Objective Proficiency Measures

In Part 2 of the study, participants completed English and Spanish versions of two objective language proficiency tasks (i.e., Verbal Fluency and Picture Naming) in a sound-attenuated room on a computer connected to a button box and two microphones, which recorded audio in Audacity (Version 3.7.3) and Chronos (Psychology Software Tools). Stimuli were presented using E-Prime 3.0 (Psychology Software Tools). Participants were carefully briefed on the experimental procedure and completed a practice run for each task to ensure that

they understood the instructions prior to starting the experimental task. Written instructions on the screen indicated the language to be used. Bilinguals show reduced dominant language proficiency after completing objective proficiency tasks in the nondominant language, while nondominant language production is not influenced by prior dominant language use (Van Assche et al., 2013; Wodniecka et al., 2020; Branzi et al., 2016), so participants completed all tasks in the majority language (English) first and in the heritage language (Spanish) second. Across languages, all participants completed verbal fluency first and picture naming second.

Verbal Fluency (VF). In this task, participants were asked to name as many unique exemplars as possible belonging to a certain semantic category within a 30-second time limit. The task included eight categories (the same as in Baus et al., 2013 and Beatty-Martínez et al., 2020b) that were counterbalanced and evenly distributed between language blocks. The categories were *animals*, *clothing*, *musical instruments*, and *vegetables* or *body parts*, *colors*, *fruits*, and *furniture*. The practice category was *transportation* across language blocks. Participants were asked to avoid generating repetitions (e.g., “car”, “cars”) and proper nouns. Verbal fluency performance was analyzed by calculating the average number of exemplars produced across categories per language.

Picture Naming (PN). In this task, participants were instructed to loudly and clearly name pictures “as quickly and as accurately as possible” in the target language and to avoid coughs, false starts, and hesitations. Participants named a total of 132 black and white line-drawn pictures over a range of lexical frequencies (Beatty-Martínez et al., 2020b; Gollan et al., 2008). The picture names are listed in the appendix with their corresponding lexical frequency values. Practice picture names included *envelope*, *train, cake*, *bear*, *peanut*, *monkey*, and *flag* for both languages. Half of the pictures had lexical frequency norms derived from CELEX (Baayen, et al., 1995), while the frequency norms of the other half (group 2) were derived from NIM (Guasch et al., 2013). Each participant named one half of the pictures in

English and the other half in Spanish. The two groups of pictures (i.e., CELEX and NIM) were assigned to language blocks in a counterbalanced order, while stimuli were presented in a randomized order within language blocks. The picture naming trial sequence started with a 500 ms fixation cross (‘+’) in the middle of the screen. Participants initiated each trial by pressing the middle button on the button box, which triggered the presentation of a picture. The picture disappeared from the display when the voice-key was triggered or after 3000 ms had passed with no response. Accuracy and response time (RT) were recorded. A response was considered accurate if it matched the intended target name, including alternative dialectal variations. Four items (i.e., apron, eggs, badge and glass) were excluded due to misidentification errors. Any RTs associated with inaccurate responses, registration errors (e.g., hesitations, repetitions or failure to trigger the voice-key), or responses that were either below 300 ms or above 2000 ms were excluded. Any remaining RTs that deviated more than 2.5 SDs from the mean of each participant were also excluded. Picture naming performance was analyzed by calculating the accuracy and average RT per language as well as for high- versus low-frequency words within each language block.

Data analysis

Data analysis was conducted in the R software (R Core Team, 2024, Version 4.5.0). Data manipulation was performed using the *tidyverse* (Wickham et al., 2019) and *Hmisc* (Harrell, 2025) toolboxes. Correlation matrices were visualized using *corrplot* (Wei & Simiko, 2024), while word clouds were generated with the *wordcloud* package (Fellows, 2018). Personal social networks were created, analyzed and visualized with the *egor* (Krenz et al., 2024), *igraph* (Csardi et al., 2025) and *sna* (Butts, 2024) packages.

When data was cleaned, one individual was removed for not completing proficiency tasks. LHQ summary statistics were created for each question and used for plotting. PNS data was organized into *egor* network plots with alters categorized by social context, ego-alter

closeness and language used. Correlation matrices were made comparing social network attributes, self-rated and objective proficiencies. Verbal fluency and picture naming results were manually scored and plotted in R. Proportions of Spanish-only and Spanish-English language use were calculated per ego network and used to predict verbal fluency and picture naming outcomes via linear regression.

Results

Language History Questionnaire

While 84.2% of participants had their primary education in the U.S., for secondary education, 94.7% of participants were schooled in the U.S. Participants who attended public high schools made up 92.1% of the sample. Participants' socioeconomic statuses were as follows: 10.5% lower working, 28.9% working, 28.9% lower middle, 21.1% middle, and 10.5% upper middle. As expected, 97.3% of participants had at least one Spanish-speaking primary caregiver, 59.5% had English-speaking caregiver(s), and one participant's caregiver(s) spoke Cantonese (2.6%). Twenty-one respondents had at least one bilingual caregiver.

While 64.9% of participants reported speaking two languages, 26.3% speak three, 7.9% speak four, and one participant (2.6%) speaks five languages. In addition to Spanish and English, the sample of this study also included non-native speakers of French, German, Italian, Portuguese, Japanese, Mandarin, Cantonese, ASL, and Korean. The mean age of English acquisition was 3.81 years (min = 0, max = 11, *SD* = 2.68), while the mean age of Spanish acquisition was 0.42 years (min = 0, max = 6, *SD* = 1.24). On average, self-rated Spanish proficiency was lower and more variable across four dimensions (reading: *M* = 8.65, *SD* = 1.3; speaking: *M* = 8.7, *SD* = 1.3; understanding: *M* = 9.4, *SD* = 0.98; writing: *M* = 7.6, SD = 1.8) compared to self-rated English proficiency (reading: *M* = 9.8, *SD* = 0.42; speaking: *M* = 9.6, *SD* = 0.61; understanding: *M* = 9.9, *SD* = 0.34; writing: *M* = 9.6, *SD* = 0.73) (Figure 2).

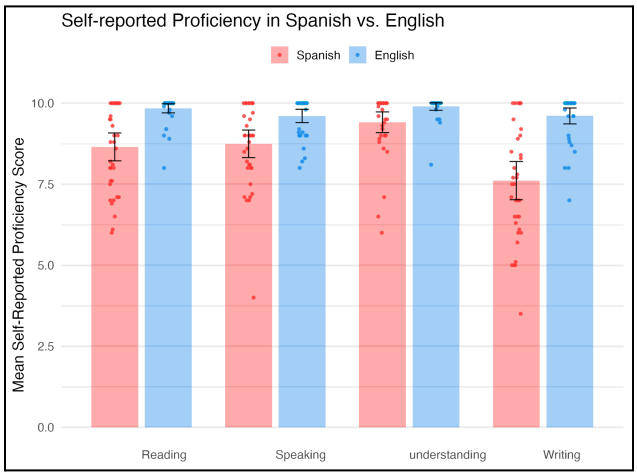

Figure 2. Self-reported proficiency per language on a scale with individual points, mean scores and SE bars.

While most participants reported more English use (*M* = 64.2%, *SD* = 14.8) than Spanish (*M* = 35.7%, *SD* = 18.4), percentages of language use varied between individuals, with 8 reporting balanced language use (i.e., around 50% use per language). In family contexts, most participants reported either using Spanish-only (family household: 59.5%, extended family: 63%) or both languages (family household: 37.8%, extended family: 37%), with no reports of English-only use with extended family (family household: 2.7%). Use of both languages was most common in the social context (65.7%), followed by work (57.1%). English-only use was prominent across school (68.6%), social (31.4%) and work (39.3%) contexts, with school being the only context with no reported monolingual Spanish use (Figure 3).

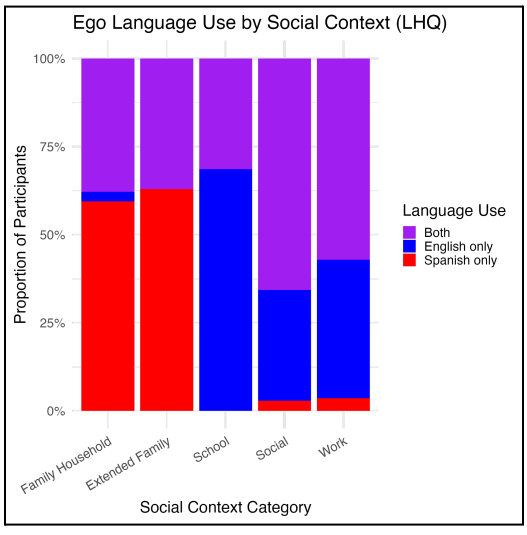

Figure 3. Proportions of reported language use profiles per social context.

On average, code-switching frequencies were highest in the social (*M* = 3.5, *SD* = 1.1) and household family (*M* = 3.2, *SD* = 1.3) contexts, and relatively similar across extended family (*M* = 2.5, *SD* = 1.5), school (*M* = 2.4, *SD* = 1.1) and work (*M* = 2.4, *SD* = 1.2). Some participants reported code-switching in contexts where they previously indicated generally monolingual language use (i.e., Spanish- or English-only, Figure 4). Precision, necessity, habit and lexical gaps were the most commonly reported reasons for code-switching.

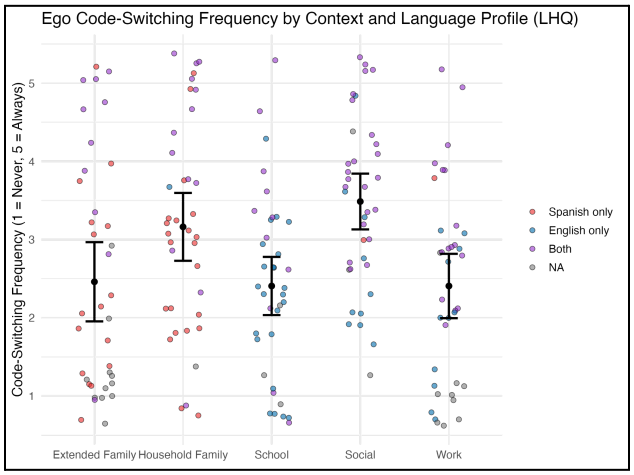

Figure 4. Codeswitching frequency per context, with mean points and CI bars. Points are color-coded by general language use per context.

Personal Network Survey

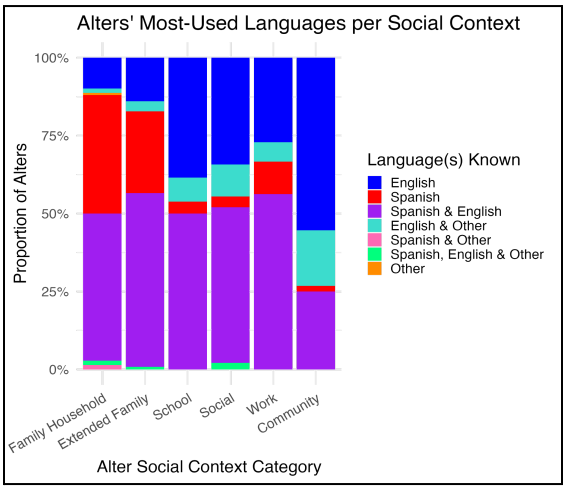

Figure 5. Proportions per context of alters' most-used languages.

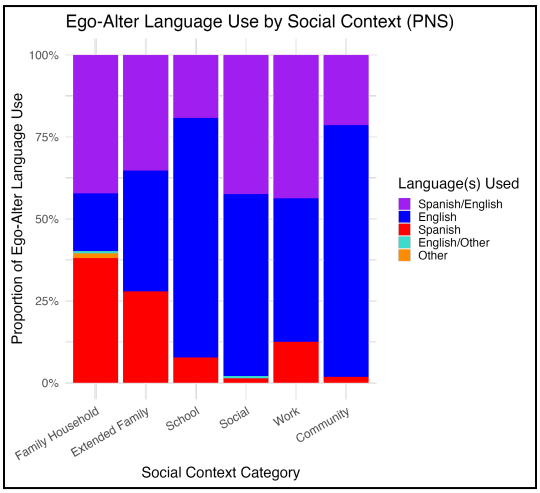

Figure 6. Proportions of ego-alter language use per context.

Reports of alters' most commonly used languages (Figure 5) point to interactional demands for ego-alter language use. Ego-alter language use results (Figure 6) show the highest proportion of English use with alters in the community and school contexts, followed by social and then work. The highest proportion of Spanish ego-alter language use was in the family household context, followed by extended family. Codeswitched Spanish-English use was most common with alters in the family household, social and work contexts (Figure 6).

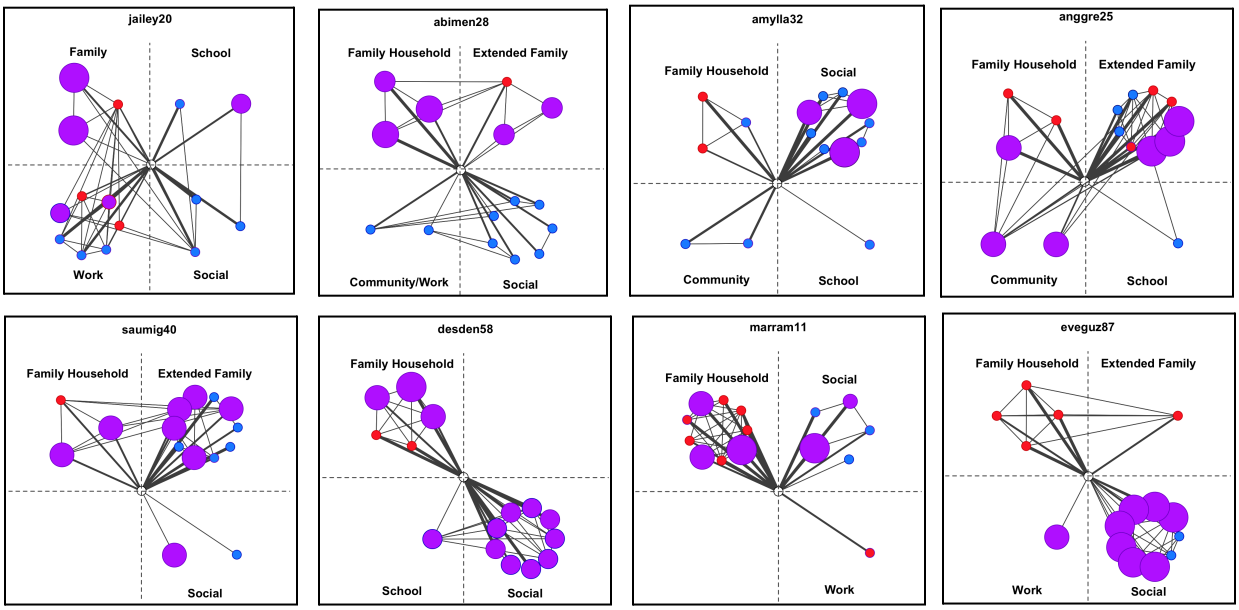

Figure 7. Personal networks of LHQ balanced bilinguals with alters categorized by social context. Node size was scaled by codeswitching frequency and edge thickness was scaled by ego-alter closeness.

Personal network plots were generated for the self-reported balanced bilinguals (Figure 7) and for outliers on objective proficiency measures (Figure 8).

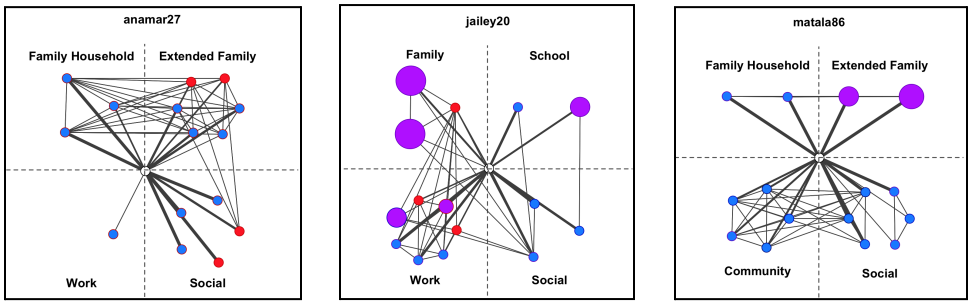

Figure 8. Personal networks of VF & PN outliers with alters categorized by social context. Node size was scaled by codeswitching frequency and edge thickness was scaled by ego-alter closeness.

Verbal Fluency

The majority of participants named more English exemplars than Spanish, although 6 individuals had better Spanish performance (Figure 9).

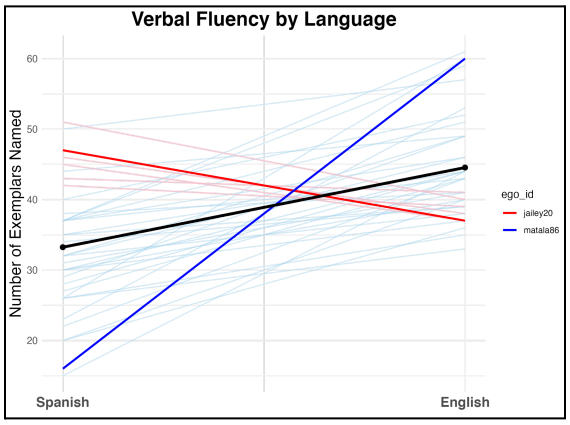

Figure 9. Slope plots of verbal fluency scores by language with highlighted egos. Group mean is in black.

Picture Naming

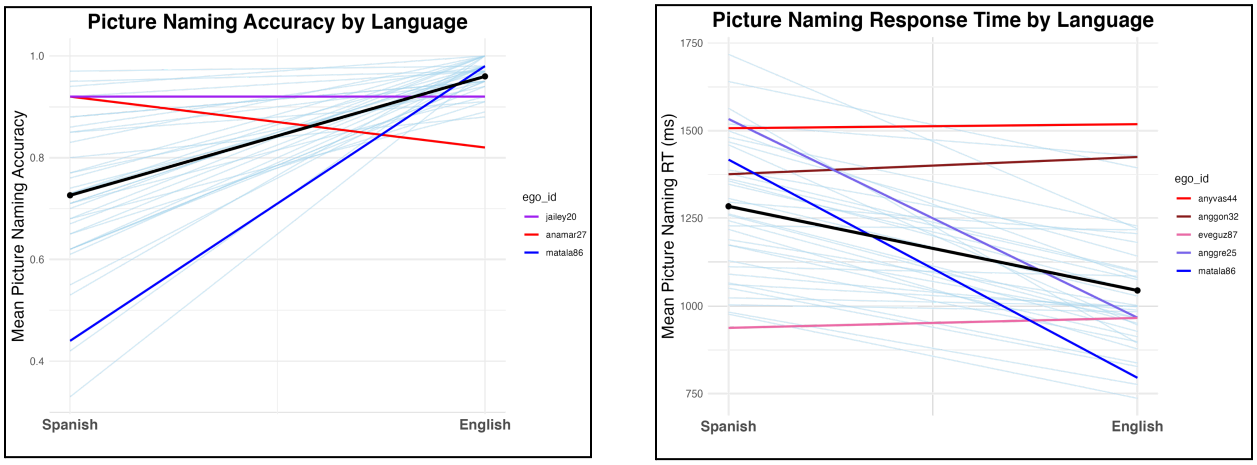

Figure 10. Picture naming outcome slope plots by language, with group means in black and highlighted egos. Left: Picture naming accuracy with English-dominant, Spanish-dominant balanced ego outliers. Right: Picture naming response time with English- and Spanish-dominant ego outliers.

All participants except two had higher PN accuracy in English (Figure 10, left). Similarly, English RT for the majority of participants was faster than Spanish RT (Figure 10, right).

Correlation matrices

As seen in Figure 11, proportion of Spanish-only ego-alter language use in social networks showed positive correlations with LHQ self-rated proficiency, picture naming accuracy

and RT. Conversely, the proportion of English speakers in the network negatively correlated with Spanish PN accuracy. In Figure 12, a frequency effect was observed where proportion of ego-alter Spanish use correlated more strongly with picture naming accuracy and RT for low frequency words than high. Spanish VF and LHQ self-rated proficiencies were also more strongly correlated with PN accuracy and RT for low frequency words versus high (not pictured). Self-rated proficiencies were only correlated with picture naming outcomes for high-frequency words (not pictured), showing an opposite frequency effect for this measure across languages. English and Spanish low-frequency PN accuracy were negatively correlated with each other.

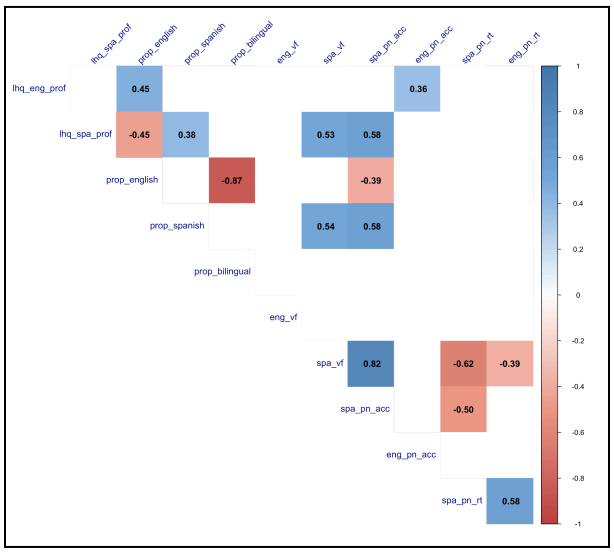

Figure 11. Correlations between LHQ proficiencies, ego-alter language use proportions per network, VF scores and PN accuracy and RT averages.

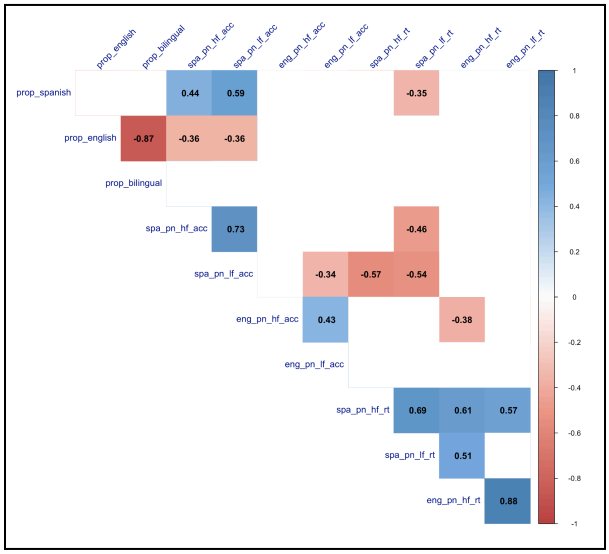

Figure 12. Correlations between ego-alter language use proportions and PN accuracy and RT per word frequency group.

Linear regression

Linear regression analysis revealed that the proportion of in-network Spanish-only language use significantly predicted Spanish verbal fluency scores (β = 38.59, SE = 10.29, t = 3.749, $p < 0.001$). The verbal fluency model (Figure 13) accounted for 29.87% of the variance in Spanish verbal fluency performance (R^2 = 0.299, F = 14.06, $p < 0.001$), with a baseline intercept of 26.1 when no Spanish speakers are in-network.

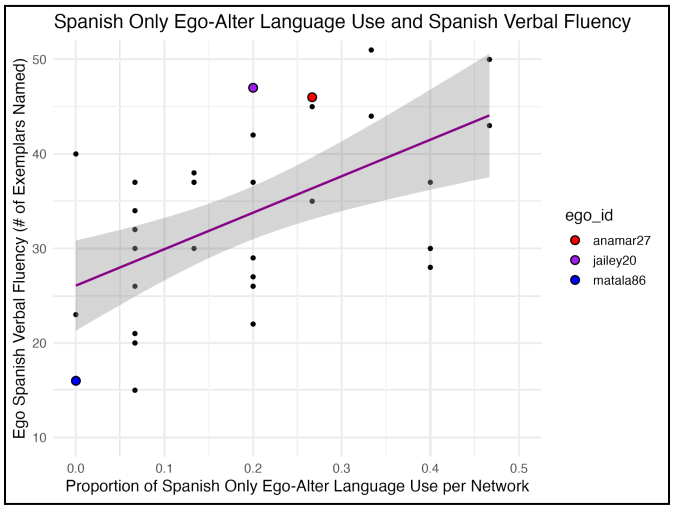

Figure 13. Linear model for Spanish-only ego-alter language use vs. Spanish VF, with egos of interest highlighted.

In addition, the proportion of Spanish speakers in participants' networks significantly predicted Spanish picture naming accuracy (β = 0.71, *SE* = 0.16, *t* = 4.46, *p* < 0.001). The PN accuracy model (Figure 14) accounted for 37.6% of the variance in Spanish picture naming accuracy (R^2 = 0.376, *F* = 19.86, *p* < 0.001), with a baseline intercept of 60% PN accuracy when no Spanish speakers were present in the network.

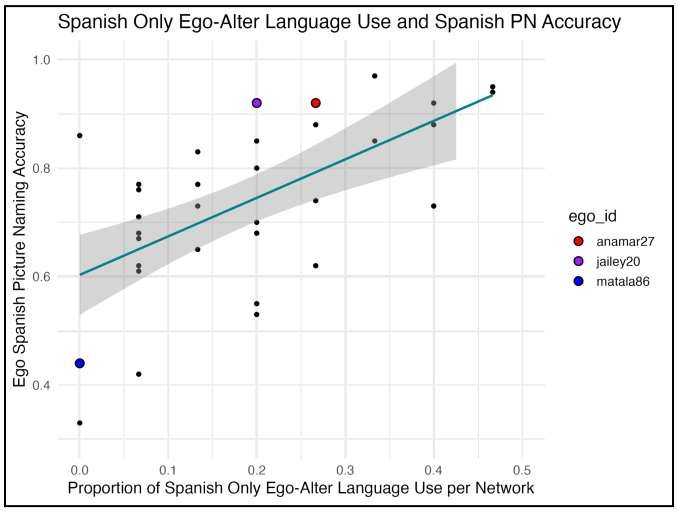

Figure 14. Model for Spanish-only ego-alter language use vs. Spanish PN accuracy, with interesting egos in color.

Finally, the proportion of in-network Spanish speakers significantly predicted Spanish PN RT (β = -528.79, *SE* = 230.86, *t* = -2.291, *p* = 0.029). The picture naming RT model (not pictured) accounted for 13.72% of the variance in Spanish picture naming RTs (R^2 = 0.137, *F* =

5.247, p = 0.029), with a baseline intercept of 1377.4 milliseconds when no Spanish speakers were present in the network.

Discussion

The purpose of this study was to gain a better understanding of heritage bilingual language experience by comparing language history, social network and objective proficiency measures. The results of the Language History Questionnaire provide a generalized heritage bilingual profile: participants demonstrated early acquisition of their heritage language (Spanish, mean age = 0.42 years) followed by later English acquisition (mean age = 3.81 years), consistent with typical heritage speaker developmental patterns. Self-rated proficiency scores revealed asymmetrical bilingual competence, with participants reporting higher English proficiency across all domains compared to Spanish, particularly in more formal literacy skills where Spanish writing proficiency showed the greatest variability (SD = 1.8). Language use patterns reflected the dominant societal language influence, with English comprising approximately two-thirds of participants' overall language use (64.2%). The compartmentalized nature of language use was evident, with monolingual Spanish being used the most with family, while monolingual English use dominated school, social and community contexts (Fig. 3). Notably, codeswitching was reported even in contexts where participants reported predominantly monolingual language use (Fig. 4), with the most commonly reported reasons (precision, necessity, habit, and lexical gap) suggesting that codeswitching serves as an essential communication tool for many heritage bilinguals.

Do social network measures reveal insights that the LHQ alone cannot?

As predicted, LHQ reports failed to capture variability in bilingual language use at the interpersonal level, as evidenced by indications of codeswitching in reportedly monolingual contexts. The discrepancy between LHQ reports of typical language use and codeswitching frequencies per social context highlight how generalized measures of language experience fail

to capture the inherent nuance and interpersonal variability of bilingual language use. Moreover, the substantial codeswitched Spanish-English use revealed by PNS data, particularly in family household, social, and work contexts, indicates that heritage bilinguals navigate complex multilingual repertoires that cannot be captured by categorical language choice questions alone.

In addition, personal network reports reveal significantly more monolingual English use in the social context, compared to LHQ results, where social monolingual English use is least-reported out of all contexts. This notable discrepancy evidences that generalized measures fail to capture variation in language use at the interpersonal level. Furthermore, reports of language use per social context on the LHQ (Fig. 3) give the impression that there is no monolingual English use in the extended family context and very little with household family. However, PNS reports of ego-alter language use (Fig. 6) reveal a substantial amount of monolingual English use across family contexts. These results align with the fact that many heritage bilinguals have family members who are monolingual English speakers, creating a communicative demand for compartmentalized English use with certain family members. This interpersonal variation in language use patterns has important implications for understanding heritage language maintenance, as it reveals that even within contexts traditionally viewed as Spanish-dominant (i.e., family), heritage speakers may have limited opportunities for sustained Spanish-only interaction with certain network members. These findings suggest that researchers relying solely on traditional language history questionnaires may significantly underestimate the complexity of heritage bilinguals' language practices, particularly the extent of English-only interactions within supposedly Spanish-dominant contexts.

Visualizations of individual social networks further illuminate the heterogeneity that exists even among participants who appear linguistically similar based on aggregate measures. While traditional approaches might assume similar patterns of language use for individuals who report balanced (i.e, 50/50) language use, network data reveals that this obscures meaningful

differences in how individuals use their languages across social contexts. The compositional diversity observed among the eight balanced bilinguals (Fig. 7), who maintain relatively higher proportions of Spanish monolingual and bilingual network members compared to English-dominant heritage bilinguals like matala86 (Fig. 8), demonstrates that identical self-reported language use proportions can emerge from vastly different social configurations. Even participants with similar network compositions may employ distinct language use strategies, as evidenced by abimen28 and eveguz87, who both segregate language use but in opposite directions – eveguz87 only uses monolingual Spanish in family contexts while codeswitching or using English with non-family members, whereas abimen28 reserves monolingual English for non-family relationships and codeswitches or uses Spanish within the family domain (Fig. 7). This detailed social network approach illustrates how heritage bilinguals who report identical proportions of general language use often employ diverse patterns of language use within their social networks that traditional measures fail to capture.

Do interactional patterns of language use relate to objective proficiency outcomes in the heritage language (i.e., Spanish)?

The granular examination of individual social networks provides crucial insights into how interpersonal language practices may relate to differential proficiency outcomes, revealing patterns that generalized measures cannot capture. By analyzing specific social networks alongside performance data, we can explore potential connections between interactional patterns and heritage language abilities. The contrasting cases of matala86 and jailey20 (Fig. 8) illustrate this relationship. While matala86's predominantly English-oriented network (i.e., monolingual English use with 13 of 15 alters) and absence of monolingual Spanish interactions coincided with substantially higher English verbal fluency (60 exemplars) compared to Spanish (16 exemplars), jailey20's more balanced network composition – using monolingual Spanish with 3 alters and codeswitching with 5 others – aligned with her unique achievement of equal

cross-linguistic picture naming accuracy (92% in both languages). Anamar27 was the only participant with superior Spanish picture naming accuracy (92%) over English (82%), which coincided with a compartmentalized network structure, where she maintains monolingual Spanish interactions with only 4 of her 15 network members while using English with the remainder. Notably, anamar27 reported that all alters in her network typically speak Spanish, yet she chooses to use monolingual English with the majority of them, suggesting that her superior Spanish performance may be linked to the quality and exclusivity of her Spanish-only interactions rather than simply the availability of Spanish-speaking network members. These individual profiles suggest that specific interactional patterns within one's social sphere appear to be associated with differential heritage language processing, supporting the notion that social network composition may play a meaningful role in shaping cognitive-linguistic performance.

In addition, linear regression analyses provide strong evidence that interactional patterns of language use are significantly related to objective proficiency outcomes in the heritage language. The proportion of Spanish-only language use within participants' social networks emerged as a robust predictor of Spanish verbal fluency performance, demonstrating that increased exposure to monolingual Spanish interactions enhances productive lexical access. Similarly, the proportion of in-network Spanish-only language use significantly predicted both Spanish picture naming accuracy and response times, indicating that greater network density of heritage language speakers facilitates more efficient lexical retrieval processes. The baseline intercepts reveal the practical implications of these network effects: participants with no Spanish speakers in their networks showed substantially reduced verbal fluency scores (26.1) and picture naming accuracy (60%), along with slower response times (1377.4 ms), compared to those with higher proportions of Spanish-speaking network members. Notably, the proportion of network Spanish use showed stronger correlations with low-frequency word processing than high-frequency words for both picture naming accuracy and response times, suggesting that

social network composition particularly influences access to less common lexical items that require sustained heritage language exposure. The negative correlation between English and Spanish low-frequency picture naming accuracy suggests a potential trade-off in cross-linguistic processing for less frequent lexical items. These findings demonstrate that heritage language proficiency is not simply a product of individual characteristics or broad contextual factors, but is strongly associated with the specific interactional patterns and language practices in one's immediate social network, supporting the need for a socially-situated understanding of bilingual language use.

The relationship between social network variables of bilingual language use and objective proficiency demonstrated in the present study reflects a broader paradigm shift in how bilingualism is conceptualized within cognitive and language sciences. Historically, bilingualism was stigmatized and avoided as a research topic due to early intelligence testing claims that positioned it as harmful to children, leading parents to withhold heritage languages from their children (Bialystok et al., 2022). Although academic perspectives on bilingualism have shifted dramatically in recent decades, heritage language maintenance continues to decline sharply across generations. Given that in Southern California, less than 10% of third-generation immigrants can communicate in their heritage language (versus 45% of immigrants who arrived as children under the age of 13) (Commission on Language Learning, 2016), there is a pressing need to accurately measure heritage bilingual language experiences and relate them to objective proficiency.

The network-based evidence presented here provides particularly strong support for the Adaptive Control framework, which posits that bilingual language processing is fundamentally shaped by interactional context and social demands. The finding that network proportions of Spanish-only language use predicted objective proficiency outcomes aligns with the framework's emphasis on how different interactional contexts create distinct cognitive demands

that adaptively tune language control mechanisms. The frequency effects observed—where network Spanish use more strongly predicted low-frequency word processing—support the adaptive control principle that sustained exposure to demanding linguistic contexts (monolingual Spanish interactions requiring access to less common vocabulary) enhances language-specific processing efficiency. Rather than viewing bilingualism as a deviation from normative language processing, current perspectives recognize that bilingualism fundamentally alters the structure and function of the mind (Kroll & Bialystok, 2013), making the study of bilingual experience essential for understanding how linguistic and social contexts shape cognition and language processing more broadly. These results demonstrate that heritage language maintenance is critically dependent on maintaining access to Spanish-speaking interlocutors within increasingly English-dominant social environments, highlighting why the systematic compartmentalization of Spanish to family contexts accelerates language shift and underscoring the need for interpersonal-level analysis to understand intergenerational language transmission in linguistically diverse communities like San Diego.

Limitations

The primary limitation of the present study was the brief time frame for experiment design, data collection and analysis, which is unavoidable for an undergraduate honors thesis. Because time constraints were the source of caveats such as the small sample size (n = 38) and relatively surface-level data analysis, the present thesis serves as an explorative introduction to the burgeoning potential of social network analysis as a contextualized measure of bilingual language experience.

Outside of the brief timeframe of the honors program, another key limitation of this approach is that data only represents a current snapshot of participants' sociolinguistic experience, which does not reflect dynamic changes in language use over time (e.g., sociolinguistic networks during childhood, adolescence, etc.). Because university students are

the population sampled in this study, results primarily reflect the sociolinguistic networks and behaviors of young adults. Although future research could sample different age ranges to better understand language dynamics across the lifespan, it is difficult to obtain a true longitudinal representation of participants' linguistic experiences in their ever-evolving social networks. Similarly, the methodological choice of having respondents report fifteen alters each may only provide a limited mapping of their social network, possibly people who are closest or most salient to the participant. To mitigate this caveat, participants were instructed to list alters from all contexts of their life with whom they frequently interacted over the past year.

Although the LHQ was carefully customized for the present study with the input of Spanish-English bilingual laboratory members with local (i.e., Southern Californian) insights, data analysis revealed minor unforeseen caveats. For one, there is a slight discrepancy between social context categories across the two questionnaires: while the PNS includes "community" (non-relatives from shared living spaces) as a social context category, the LHQ does not. PNS "community" data could not be directly compared to the LHQ because of this, which did not pose any significant issue for the present study but is worthy of noting. Secondly, while the LHQ in the present study includes general reports of the percentage of time spent and languages used in each social context, it does not ask participants to estimate their percentages of language use per context. This causes an overgeneralized language profile per context, which becomes apparent when participants indicate code switching in contexts they reported only using one language in (e.g., Spanish only) on average. Fortunately, the results of the present study support the assertion that LHQ overgeneralizations can be successfully circumvented by the PNS.

Another key caveat of this approach to surveying sociolinguistic networks is that self-report data is prone to measurement biases. For instance, individuals who are not conceptually familiar with the concept of code-switching may struggle to understand what

code-switching is and what constitutes it. To avoid this caveat, the term “codeswitching” was replaced by its operational definition, “switching between two or more languages in one interaction”, whenever possible in the questionnaires. Issues with memory constitute another confound for self-report data, in which participants misremember or struggle to remember accurate representations of their experience. While this is a more substantial limitation of the Language History Questionnaire, the key measure of this study is the Personal Network Survey, which focuses more on frequently recurring interactions within a social network, which people are generally accurate at recalling (Parkinson et al., 2017). Lastly, code-switching behaviors carry social stigma in many contexts (e.g., code-switching reflects an inability to speak either language correctly). Social desirability bias, in which participants respond in ways they perceive as more socially appealing (Brenner & DeLamater, 2017), likely has less of an influence because of the online, solitary, de-identified nature of the study. However, identity bias (Brenner & DeLamater, 2017) may be a source of overreporting or underreporting language experiences due to internalized conceptions of self; for instance, underreporting Spanish language use because of internalized shame related to one’s cultural identity or language experiences, or overreporting Spanish language use due to a desire to be more competent in one’s heritage language. However, identity bias is not a universal phenomenon but rather a reflection of the extent to which societal, community and group norms are internalized by an individual (Brenner & DeLamater, 2017).

Future Directions

A social network approach to language science provides a wealth of opportunities for measuring the interactional dynamics of everyday language that could not feasibly be included in the scope and timeframe of this study. Further research into interpersonal variables such as ego-alter codeswitching frequency, closeness, frequency and mode of contact may reveal significant relationships between interpersonal dynamics and patterns of bilingual language use

In addition, compositional attributes can be analyzed alongside social network structure, which may offer valuable insights into the role of bilinguals in their linguistic environment.

As previously mentioned, future adaptations of the present LHQ may benefit from including a question about percentage of language use per social context. Should future researchers wish to study alter language(s) known in relation to ego language experience, the PNS must be adapted to capture that information. Including questions about language brokering behavior, in which bilingual individuals translate and interpret between people who cannot speak the same languages (Morales & Hanson, 2005), may significantly benefit future studies. Further research could assess language brokering behavior alongside structural social network variables such as language betweenness – how crucial the ego is for connecting alters from different language communities (McCarty, et al., 2019). When related to proficiency outcomes, language brokering and language betweenness may reveal crucial insights into what patterns of language experience correspond with higher proficiency in the heritage language.

In California alone, there are millions of multilinguals that constitute prolific complex linguistic environments that future projects could assess. Locally, social network research on bilinguals in San Diego could be expanded for a more comprehensive image of the many diverse regional language environments. It would be particularly interesting to compare the patterns of bilingual language use between different universities (e.g., UCSD, SDSU), regions (e.g., North County, South Bay) or cities (e.g., Chula Vista, El Centro) within San Diego County to better map the county's linguistic ecosystem. Future research could also address the linguistic conditions surrounding the Mexico-U.S. border, with potential focuses being sociolinguistic dynamics in Tijuana and cross-border commuters. The Personal Network Survey could also be adapted to investigate the role of interactional context in various multilingual populations from different linguistic environments around the world. These methodological and geographic expansions would ultimately contribute to a more nuanced understanding of how

social networks shape multilingual language practices across diverse communities and contexts, with important implications for understanding correlates of language maintenance across generations.

Conclusion

This study demonstrates that personal network analysis provides a fundamentally more nuanced and predictive approach to understanding bilingual language experience than traditional generalized measures. By examining the social networks of 38 Spanish-English heritage bilinguals, we have shown that the proportion of Spanish-only interactions within one's immediate social network significantly predicts objective heritage language proficiency outcomes in ways that language history questionnaires cannot capture alone. The findings reveal that traditional measures systematically underestimate the complexity of bilingual language use at the interpersonal level, missing crucial patterns such as codeswitching in reportedly monolingual contexts. Social network composition emerges as a robust predictor of heritage language maintenance, with Spanish-only network interactions accounting for up to 38% of the variance in picture naming accuracy.

In regions such as Southern California where heritage language loss accelerates across generations, understanding the social mechanisms that support language maintenance becomes critically important. The network-based evidence suggests that heritage language preservation depends on maintaining access to heritage language speakers within increasingly English-dominant social environments, rather than simply on family transmission or individual motivation. From a methodological perspective, this study establishes personal network analysis as a valuable tool for capturing the inherently social nature of multilingual experience. This approach opens new avenues for investigating how social context shapes language processing across diverse multilingual populations worldwide and provides empirical support for socially-situated approaches to understanding bilingualism. The evidence presented

demonstrates that heritage language maintenance is not an individual endeavor but a fundamentally social process embedded within interpersonal relationships. By revealing these social dynamics, personal network analysis offers both researchers and communities new tools for understanding and supporting the complex pathways through which languages persist across generations in multilingual societies.

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