EFFECTS OF LANGUAGE DOMINANCE IN SPANISH-ENGLISH BILINGUAL SPEAKERS

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ABSTRACT

Despite the rise of globalization and increasing multilingualism, the effect of language dominance on thought and perception in bilingual speakers has received little attention. This study examines the semantic networks of Spanish-English bilingual adults and monolingual English-speaking peers to determine whether language dominance structures the semantic space of a bilingual speaker to more closely match the semantic space of a monolingual speaker of the dominant language. It is predicted that semantic ratings produced by English-dominant bilinguals will correlate more closely to the semantic ratings of monolingual English-speaking participants than ratings produced by Spanish-dominant bilinguals. Spanish-English bilinguals (n=20) completed the *Bilingual Language Profile* regarding language use, attitudes, and fluency (Birdsong, Gertken, & Amengual, 2012). Spanish-English bilingual participants and monolingual English-speaking participants (n=20) then rated a series of translationally equivalent nouns (n=80) according to sound, color, morality, valence, size, and position. Using these ratings, a Euclidean distance matrix containing the ratings of English-dominant bilinguals, Spanish-dominant bilinguals, and English monolinguals was analyzed within and between groups using hierarchical cluster analysis, matrix comparisons (Mantel Tests), Spearman correlations, and qualitative k-means clustering analysis. Results suggest the possibility of dynamic interconnection between languages, with semantic connection weights determined by the dominant language (Malt et al, 2015). However, more research is needed to draw firm conclusions.

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CHAPTER 1

INTRODUCTION

There is a pressing need for more research regarding thought and language use among bilingual Spanish-English speakers in the United States. According to the 2016 U.S. Census, individuals who self-identify as Hispanic/Latino constitute 17.8% of the United States population (United States Census Bureau, 2017). Further, it is estimated that by the year 2060, Hispanic/Latino individuals will make up approximately 28.6% of the nation's population (United States Census Bureau, 2017). According to the 2016 American Community Survey, 40 million U.S. residents over the age of five speak Spanish at home—an increase of 133.4% since the year 1990 (United States Census Bureau, 2017). The use of Mainstream American English (MAE) as the normative language in educational and workplace environments, however, reinforces English usage among many bilinguals (Wolfram & Schilling, 2016). In fact, nearly 25% of Hispanic/Latino adults "mainly use English", and the number of English-Spanish bilinguals who speak "mainly English" is projected to grow (Krogstad & Gonzalez-Barrera, 2015). Despite this large demographic presence of English-dominant Spanish-English bilinguals, little research has been done to address the unique needs of this population. Specifically, much remains to be learned about the semantic spaces of bilingual individuals.

The theory that bilingual individuals maintain semantic systems that are unique from those of their monolingual peers has received support from several studies of bilingual naming and categorization (Ameel, Storms, Malt, & Sloman, 2005; Malt, Ping, Pavlenko, & Ameel, 2015; Pavlenko & Malt, 2011). Current theory in bilingual semantics favors a connectionist model of the semantic space, with the possibility for dynamic interactions between languages (Malt et al 2015; Pavlenko, 2009) . This study seeks to understand the effect of English language dominance on these dynamic interactions within the semantic space using both qualitative and quantitative measures. Comparing semantic ratings of translationally equivalent common nouns (n=80) between English-dominant bilingual individuals, Spanish-dominant bilinguals, and English monolinguals, will add to current knowledge of interactions between language use, language dominance, and semantic representation. Attempts to understand how language use mediates thought has a long history in the discipline of linguistics, which sets the groundwork for this study.

The Sapir-Whorf Hypothesis

The extent to which language constrains thought is a foundational question for cognitive science and the philosophy of mind. Contemporary debate regarding language-thought interactivity is often linked to Edward Sapir and his student, Benjamin Lee Whorf (Kay & Kempton, 1984). Kay and Kempton (1984) summarized three central tenets of what later became known as the Sapir-Whorf hypothesis:

1. Structural differences in syntax, semantics, and phonology within a language system will be mirrored in nonlinguistic cognitive differences in a native speaker.
2. The structure of one's native language influences or completely defines life experience and worldview
3. Semantic systems of different languages vary unconditionally

The hard-line linguistic determinism of the Sapir-Whorf hypothesis has largely fallen out of favor in academic circles. However, research investigating the three main tenets of the Sapir-Whorf hypothesis has been conducted using color naming. Kay and Kempton (1984) presented experimental participants with 56 triads of different colored paint chips. In each triad of colors, participants were asked to choose which color was least like the other two colors in the group. This experiment was tested on speakers of English and speakers of the Tarahumara language. The experiment found that English speakers tended to exaggerate differences between colors at the color name boundaries in English (i.e. blue as different from green). However, speakers of Tarahumara, whose language does not use different words to describe the colors of blue and green, did not discriminate as readily between colors at the blue-green naming boundary. Kay and Kempton hypothesized that this difference between speakers of English and Tarahumara was due to the use of a naming strategy to discriminate between very similar colors. A follow-up experiment conducted on 21 English speakers attempted to reduce the salience of lexical naming boundaries. In this experiment, English speakers were presented with triads of three color chips. Each participant was asked to explain which two color chips in each triad were most similar based on a given lexical descriptor (i.e. "Tell me which is bigger: the difference in green-ness between these two colors, or the difference in blue-ness between these two colors?"). As predicted, when participants were forced to ignore lexical boundaries between colors and focused solely on visual differences, a Whorfian effect was not seen. Kay and Kempton concluded that semantic representation and categorization of color was mediated based on lexical boundaries (Kay & Kempton, 1984).

Variations on Kay and Kempton's pioneering experiment on color perception has been replicated numerous times. Özgen and Davies (2002) found that experimental participants could be taught to discriminate a new perceptual color category boundary through laboratory training, indicating that the color category perception is somewhat flexible, and potentially affected by language. Roberson, Davidoff, Davies, and Shapiro (2005), furthered this theory by comparing native speakers of Himba and Berinmo, both languages with only five color terms, to native English speakers during a color naming and memory task. All participants were asked to name an individual color card during a simple naming task. A memory task consisted of identifying a color card that had been shown for 5 seconds, and then hidden under a cloth among several other cards. Participants were allowed to use multiple descriptors for all colors shown during both naming and identification tasks. Himba speakers produced 8.1 unique color descriptors, compared to 6.9 for Berinmo speakers and 27.6 descriptors produced by English speakers (Roberson et al., 2005). Color memory task performance correlated significantly with the number of unique descriptors produced for both Himba (0.48, $p<.05$) and Berinmo speaker (0.47, $p<.05$) (Roberson et al., 2005). This indicates that the number of unique color descriptor words is correlated with specificity of color memory for these speakers (Roberson et al., 2005). Once again, we see that access to the semantic perception of color is mediated by language (Kay & Kemper, 1984; Roberson et al., 2005). The possibility raised by these more recent experiments, that language can affect perception, has even more interesting implications for individuals who speak more than one language. Could bilingual individuals' perception and semantic representation of color, or other objects, change based on language use?

Bilingualism occurs along a continuum, which makes any investigation of bilingual semantics inherently multifaceted (Birdsong & Gertken, 2013). This continuum of bilingualism is modulated by age of acquisition of a second language (early/late), manner of second language acquisition (simultaneous/successive or acquired/learned), and degree of proficiency in a second language (compound/coordinate/subordinate bilingualism) (Moradi, 2014). This study will follow the definition used by Birdsong and Gertken (2013), who define a bilingual person as “a user of two languages” regardless of language proficiency or language dominance. Past research on bilingual individuals show that individuals who use two languages have significantly different patterns of naming and categorization as compared to monolingual peers even using simple household objects (Ameel, Storms, Malt, & Sloman, 2005; Malt et al., 2015). Because categorical perception and naming are directly related to perception of category boundaries, and conceptual semantic representation (Malt et al., 2015), these previous works form the backbone of the current study.

Category Perception and Semantic Networks in Bilingual Individuals

The question of perceptual category naming in multilingual individuals was explored by Ameel et al. (2005). The study explored two prevailing hypotheses regarding bilingual semantic networks. The first hypothesis on naming and categorical perception in bilingual individuals was referred to as the one-pattern hypothesis (Ameel et al., 2005). The one-pattern hypothesis theorizes that bilingual speakers converge the semantics of their two languages into one new semantic space. This would create a distinct naming pattern among all French-Dutch bilinguals that would differ from monolinguals in either language (Ameel et al., 2005). There are two possible variants of the one-pattern hypothesis. A strong version of this hypothesis predicts that all French-Dutch bilinguals will name and categorize all household objects in the exact same way in both French and Dutch, with no significant effect of language used during the experiment session (Ameel et al., 2005). The only significant effect seen in bilingual participants under this strong one-pattern hypothesis would be in regards to linguistic status (i.e. identity as a monolingual or bilingual speaker).

In contrast, a more moderate version of the one-pattern hypothesis would allow for French-Dutch bilinguals to show a small effect of language used during naming and sorting tasks. This could result in slightly different patterns of naming and sorting for bilinguals when naming objects in French versus when naming and sorting the same objects in Dutch. According to this moderate one-pattern hypothesis, bilingual naming and sorting patterns would show significant effects of both language use and linguistic status. However, monolingual naming and category perception would show much stronger effects of language use. A third option is possible, referred to by the authors as a two-pattern hypothesis for bilingual naming. This hypothesis predicts that bilingual speakers preserve the same semantic network as monolingual speakers in each language. Under a two-pattern model, naming and sorting choices of Dutch-French bilinguals for basic objects would be exactly the same as French monolingual speakers when speaking French and Dutch monolingual speakers when speaking Dutch. This model predicts a significant effect of language with no significant effects for linguistic status (bilingual speaker vs. monolingual speaker; Ameel et al., 2005).

Ameel et al. (2005) asked 32 native speakers of Dutch, 29 native speakers of French, and 25 Dutch-French bilinguals to complete two main tasks: naming objects and sorting objects. All objects were common household dishes. Each linguistic group was asked to name all provided objects, and then sort the provided objects into at least two categories. Bilinguals completed the experiment twice: once in each language. The experiment found support for a moderate one-pattern naming hypothesis. During naming and sorting tasks, monolingual speakers showed a larger effect of language use when naming and sorting both bottles ($F(1, 7866) = 70.17$, $p < .0001$) and dishes ($F(1, 7866) = 58.44$, $p < .001$) than did bilinguals (Ameel et al., 2005). This shows that bilinguals applied similar names and category boundaries in both languages, with only small effects of language change during experimental procedures. Monolinguals, on the other hand, showed sorting and naming that was much more strongly determined by the language used during procedure tasks (Ameel et al., 2005). This shows that bilinguals do appear to converge semantic networks between their two languages, with some differences in naming and categorization based on which language the bilingual person is currently using. Additional variation in naming and categorization patterns among bilinguals can be explained by differences in daily language use, age of L2 acquisition, and language dominance.

The Effect of Second Language Acquisition on Categorical Perception and Semantic Space

The impact of language dominance and age of language acquisition on categorical perception was explored by Pavlenko & Malt (2011). Monolinguals in English (n=20) and Russian (n=20) were compared to early English-Russian bilinguals (n=9), childhood

English-Russian bilinguals (n=9), and late English-Russian bilinguals (n=11). Early bilinguals arrived in the U.S. between the ages of one and six years of age, while childhood bilinguals arrived in the US between eight and fifteen years of age. In contrast to early bilinguals, childhood bilinguals started their education in Russian-speaking schools before continuing in the U.S. education system. Late bilinguals had moved to the U.S. from Russian-speaking countries between the ages of 19 and 27 years, and had spent the majority of their education in Russian-speaking schools (Pavlenko & Malt, 2011). These participants now used English in their work environments. All participants were asked to name common household objects, including cups, mugs, and glasses, which were ranked based on typicality on a 7-point Likert scale (Likert, 1932; Pavlenko & Malt, 2011).

Monolingual speakers of English and Russian showed a 0.37 correlation when naming common household objects in their respective languages (Pavlenko & Malt, 2011). When naming in Russian, native Russian speakers and late bilinguals showed a correlation of 0.81, while native Russian speakers and childhood bilinguals showed a 0.73 correlation (Pavlenko & Malt, 2011). Early bilinguals showed the lowest correlation with native Russian speakers at a 0.48 correlation (Pavlenko & Malt, 2011). This shows a predictable and orderly change in categorical perception and semantics based on age of arrival to the U.S. Essentially, bilinguals move further from the pattern of native speakers based on earlier age of arrival to the US and/or exposure to a majority English-speaking environment (Pavlenko & Malt, 2011). Interestingly, all participant groups, including late bilinguals, showed a shift in categorical naming of household items upon acquisition of a second language, giving further support to the theory that bilingual individuals have a modified semantic space between both languages (Pavlenko & Malt, 2011). In summary, this study further supported a modified one-pattern naming pattern for bilingual individuals, while also demonstrating that bilingual individuals can experience dynamic changes in language use throughout their lifetime.

Current Models of Bilingual Semantics

These dynamic changes in language use and thought patterns are supported in the current theory of bilingual semantics through a Modified Hierarchical Model (Pavlenko, 2009; Malt et al., 2015). This semantic model begins with basic word forms, which lead to a conceptual level of representation: the concepts these words represent, any important associations, and prototypical elements of this concept. The words *bottle* and *botella,* for example, are both translational equivalent word forms. If *bottle* and *botella* were exactly semantically equivalent, both words would evoke the exact same mental image, or concept, of a bottle (Reilly et al., in development). An alternative is also possible: *bottle* and *botella* could evoke two different mental images (*bottle* could call to mind a plastic water bottle, while *botella* could evoke a glass bottle, for example). In this alternative case, semantic representation of the concept of a bottle is directed or framed by language (Reilly et al., in development).

When a connectionist framework is applied to this modified hierarchical semantic model, influences of one language on the other can be thought of in terms of the connection weights between the word form (e.g. *bottle*) and the mental image evoked by that specific word form, the conceptual layer (Malt et al., 2015). When an individual learns a word in a second language (L2)[1] that is a direct translational equivalent to a known word in the individual's first language (L1), the semantic system will set connection weights between these equivalent words (Malt et al., 2015). An English monolingual who learns that the L2 word *botella* is a direct translational equivalent to the L1 word *bottle*, for example, will equally connect both *bottle* and *botella* to the same mental image (Malt et al., 2015). Since English is this individual's L1, the Spanish word form *botella* would be connected to the mental image of a plastic water bottle. In this case, the main conceptual image of a plastic water bottle is this person's prototypical exemplar of a bottle. Individual word forms are also connected to conceptual associations (e.g. cup, water) as well as the features that make an object a bottle (e.g. tube-shaped, receptacle for liquid) (Malt et al., 2015).

When an individual is still in the process of acquiring a second language, a recently acquired L2 word will be activated by the same features as its translational equivalent in the individual's first language, resulting in non-native use of L2 (Malt et al., 2015). A baby bottle, for example, is called *bottle* in English and shares many of the same features as this individual's prototypical exemplar of a bottle. Due to these strong English-based connection weights, if this person were attempting to name a baby bottle in Spanish, she might refer to it as a *botella*. This would be a non-native production, as a baby bottle is referred to as *mamadera* in Spanish (Malt et al., 2015). When an individual gains more experience in the L2, however, connection weights and conceptual elements of L2 word forms could be changed to more closely approximate the language system of

[1] Using this example, L1 refers to both the dominant language and the first acquired language. For the remainder of this study, L1 refers to the dominant language unless otherwise specified.

L2 native speakers (Malt et al., 2015). So, with more experience learning about names for specific drinking receptacles in Spanish (and their various features), this individual would learn that baby bottles are not called the same name as other bottles. This would lead to a shift in this individual's semantic space toward Spanish (Malt et al., 2015).

On top of this basic framework, lexical interaction is also a possibility. That is, bilingual speakers might create "cross-connections" between words in both languages that can cause adjustments not only in production of L2 words, but also in L1 semantic networks (Malt et al., 2015). There are two main possibilities for how conceptual weights in bilingual individuals can adjust. One possibility is that the connection network could stabilize after L1 is mastered, making any L2 less likely to cause change in this network. The other possibility is that the lexical network is never done changing, and can make adjustments over time (Malt et al., 2015). This means that if one gets enough linguistic input, L2 connection weights can change and become similar to those of a native speaker of that language, while creating simultaneous connection weight adjustments in the individual's L1. Using our earlier example, changes in the conceptual elements and associations related to *botella* to could, through repeated use and exposure, affect connection weights to the translationally equivalent word form *bottle.* Now, the individual's conceptualization of *bottle* could change. This person could even begin to refer to baby bottles in English using a different name, thereby changing L1 use. With increased exposure to L2, these changes would only grow stronger.

To test the possibility of a dynamic, ever-changing connectionist framework, Mandarin-English bilinguals who came to the US after age 15 (n=62) were compared to two control groups: English monolinguals (n=28) and Mandarin monolinguals (n=25)

(Malt et al., 2015). For these bilingual participants, Mandarin was designated as L1 (first acquired language) while English was L2 (second acquired language). Participants looked at images of containers and dishware and then named each image. Measures of daily language use and language proficiency ratings were also collected. Bilinguals completed the naming task in both Mandarin and English. Results indicated that progress in learning an L2 did not inhibit knowledge of the L1. Instead, both languages work together in "dynamic interaction" between both lexical-semantic systems (Malt et al., 2015). For example, Mandarin-English bilinguals who reported more frequent use of English in daily life performed similarly to monolingual English speakers when naming dishware ($r=0.43$, $p<.005$) showing that increased use of English (L2) had a "re-shaping" effect on naming patterns and the semantic space (Malt et al., 2015). Even well-established patterns of naming in Mandarin (L1) showed effects of increased L2 use. Bilinguals with increased English use and high English verbal fluency scores showed slightly lower agreement with Mandarin monolinguals when naming containers ($r= -.36$, $p<.005$) (Malt et al., 2015). This supports a view of semantic convergence between both languages, wherein advancement in use of an L2 does not necessarily lead to L1 attrition, but may lead to changes in a combined, dynamic semantic system (Malt et al., 2015). The effect of daily language use and overall language dominance on this dynamic, interconnected system requires further research. However, initial findings regarding the contributions of language dominance in the establishment of a dynamic semantic network are promising.

Language Dominance in the Connectionist Framework

Within the connectionist framework of dynamic interaction between the two languages of a bilingual individual, language dominance appears to play a significant role. Effects of language dominance were found in a syntactic judgment experiment by Rah (2010): English-dominant French-English bilinguals relied on English relative clause attachment patterns even when speaking in French, while French-dominant bilinguals did not show any influence of English relative clause attachment features. In other words, second-language learners of French who were English dominant used English patterns of clause attachment when speaking French. French-dominant English-French bilinguals, however, did not use any English clause attachment patterns in French (Gertken, 2013). In this case, language dominance has clear effects on cross-linguistic transfer, without even mentioning additional effects of language dominance that have previously been found to influence behavior such as code-switching (Basnight-Brown & Altarriba, 2007) and lexical memory representation (Heredia, 1997, seen in Gertken, 2013). Results from this study support that, in a modified one-pattern hypothesis in which connection weights are established through dynamic interaction two languages, language dominance plays a significant role in the establishment of connection weights between languages. As such, a firm understanding of the definition of language dominance and proficiency is necessary for any study regarding dual-language semantic representation.

Language Dominance in Bilingualism

Unlike language dominance, language proficiency is a relatively well-known and widely studied aspect of language acquisition and bilingualism research (Gertken, Birdsong, & Amengual, 2012). It is typically defined in explicit and measurable ways, such as grammar usage, vocabulary, pronunciation, and written/oral language comprehension (Gertken, 2013). Standardized assessments and entrance examinations, such as the GRE and the SAT, are designed to measure language proficiency of monolingual, Mainstream American English speakers (Gertken et al., 2012). As such, measures of language proficiency can be used to describe both monolingual and bilingual speakers of any given language.

Although language dominance and proficiency are related, the two concepts are not the same. Language dominance as a concept can only be used to describe individuals who use more than one language (Grosjean, 1998; seen in Gertken, 2013). Language dominance is defined by the relationship between an individual's two languages, and is therefore relativistic and individualized in nature (Gertken, 2013). As explained by Gertken et al., (2012), it is possible to be highly proficient in two languages without being dominant in either language. Such an individual would be accurately classified as a "balanced" bilingual (Gertken et al., 2012). It is also possible to be dominant in one language without being highly proficient in that language (Birdsong et al., 2012).

Language dominance is relativistic and varies for each individual, which makes it difficult to measure (Birdsong & Gertken, 2013). Previously, dominance has been assessed using experiential criteria, such as age of acquisition, current country of residence or length of residence in a foreign country, and current patterns of language use (Chincotta & Underwood, 1998; Grosjean, 1982; Hazan & Boulakia, 1993; seen in Gertken et al., 2012). Psycholinguistic criteria—reaction times in picture naming tasks, vocabulary, reading speed, and average sentence length—have been compared in an individual's two languages as another way to quantify dominance (Favreau & Segalowitz, 1982; Flege, MacKay, & Piske, 2002; Golato, 2002; Magiste, 1992; Treffers-Daller, 2011; seen in Gertken et al., 2012). Psychosocial criteria, such as personal feelings of comfort or patterns of use with family (Grosjean & Miller, 1994; seen in Gertken et al., 2012), and subjective personal assessment (Gertken et al., 2012; Talamas, Kroll, & Dufour, 1999) are more individualized ways of assessing dominance. At the most basic level, however, language dominance has been described as the language that is the most accessible for daily tasks of speaking and thinking (Harris, 2006). Current assessments to measure language dominance include the *Bilingual Dominance Scale* (Dunn & Fox Tree, 2009) and *Language Experiences and Proficiency Questionnaire (LEAP-Q)* (Marian, Blumenfeld, & Kaushanskaya, 2007). In addition to these measures, the *Bilingual Language Profile* (BLP) (Birdsong, Gertken, & Amengual, 2012) was created to measure dominance on a dynamic and individualized continuum (Gertken et al., 2012). The BLP was selected as a primary measure of dominance in this study due to its individualized and continuum-based approach to assessing dominance (Birdsong et al., 2012).

CHAPTER 2

OBJECTIVES

The purpose of this thesis is to quantitatively and qualitatively measure semantic differences between English-dominant and Spanish-dominant bilingual individuals and their English monolingual peers. A quantitative and qualitative experiment regarding English-dominant bilingual individuals is necessary due to the significant presence of this population in all areas of life in the U.S. To date, there has been no formal investigation into the semantic space of English-dominant bilinguals, despite their large demographic presence. Despite compelling evidence of a modified one-pattern convergence hypothesis moderated by dynamic interconnections between languages in the semantic spaces of bilingual individuals (Malt et al, 2015; Rah, 2010), the effect of language dominance on the establishment of dynamic semantic connection weights has been underexplored. A firmer understanding of how language dominance affects the semantic spaces of bilingual individuals may lead to more individualized options in the fields of education and clinical speech-language therapy for bilingual individuals.

Research Questions and Predictions

The research question is the following: *Will language dominance structure the semantic space of a bilingual speaker to more closely match the semantic space of a monolingual speaker of the dominant language?* It is hypothesized that bilingual individuals who are English dominant will have a semantic space that more closely resembles the semantic space of English monolingual speakers than will Spanish-dominant bilingual individuals. It is predicted that semantic ratings produced by English-dominant bilinguals will correlate more closely to the semantic judgment ratings of monolingual English-speaking participants at Time 1 when compared to ratings produced by Spanish-dominant bilinguals. This moderate one-pattern semantic pattern of semantic representation must be influenced by dynamic interaction between languages, as in the connectionist model (Malt et al, 2015), wherein an individual's dominant language serves to structure connection weights between individual words and their semantic referents in the semantic space.

CHAPTER 3

STUDY INFORMATION

This thesis is based on a developing study by Reilly et al. (in development). High dimensional componential semantic modeling is used to examine component aspects of each test item based on a six-dimensional semantic space (Crutch et al., 2013; Primativo, Reilly, & Crutch, 2016; Reilly, Peelle, Garcia, & Crutch, 2016 seen in Reilly et al., in development). Experimental results from Reilly and colleagues are analyzed in conjunction with language dominance data gathered from each participant to determine the effect of language dominance in structuring the bilingual semantic space.

Participants

Participants include two groups of young adults recruited from Temple University as well as other universities in the greater Philadelphia area. All participants were, by self-report, unaffected by dyslexia or language-learning disabilities (Reilly et al., in development). Monolingual participants (n=20) included self-identified native English speakers with no previous coursework in or knowledge of Spanish [mean age =21.85; years; mean years education = 14.65 years; 15 F/5M] (Reilly et al., in development). Bilingual participants (n=20) included self-identified bilingual Spanish-English speakers [mean age = 22.9; mean years education =15.8 years; 15 F/5 M] (Reilly et al., in development). All bilingual participants completed a prescreening "Can-do Checklist" regarding Spanish language ability to prior to selection for the study (Higby, 2016). Bilingual participants included in the study showed a wide range of language dominance and language learning backgrounds (Appendix B; Reilly et al., in development). The study includes simultaneous bilingual participants (n=6) who learned both English and

Spanish from birth; successive bilingual who learned English as a second language (n=11); and successive bilinguals who learned Spanish as a second language (n=2). Some participants (n=14) reported living in a foreign country for more than one year. Monolingual and bilingual participant groups showed no significant differences based on age [t(32.6)=1.04, p=.33] and were matched exactly on sex [15f/5m] (Reilly et al., in development).

Research Site

This study was administered at the Eleanor Saffran Center for Cognitive Neuroscience on the campus of Temple University. This site is located on Temple's Main Campus in Philadelphia. Participants for the study were recruited according to standards set by the Temple University IRB. This study was carried out in full cooperation with the Temple University IRB. All eligible participants provided informed consent to participate in the study. Participants were compensated minimally ($25) for their time.

Instruments and Protocols

This study relies primarily on the BLP self-report questionnaire (Birdsong, Gertken, & Amengual, 2012) for information regarding language use and attitudes. Bilingual participants were screened using the Can-do Language Checklist (Higby, 2016). All participants completed semantic ratings using Qualtrics software. Language proficiency measures, including the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983), a verbal fluency task, and a word association task were administered using E-Prime 2.0 professional software (Psychology Software Tools, Pittsburgh, PA). All instructions for semantic ratings and language proficiency measures are included in Appendix A.

Stimulus Selection

Stimuli consisted of 80 translationally equivalent nouns in both English and Spanish. The MRC Psycholinguistic Database (Coltheart, 1981) was used to search for stimuli based on part of speech (noun), regardless of concreteness values (Reilly et al., in development). Google Translate (English to Spanish) and Word Reference online dictionary were used to find translational noun equivalents in Spanish. All translational equivalents were confirmed by a native Spanish speaker. Direct cognates (e.g. *television, televisión*), words with more than one possible grammatical role (e.g. *gesture*), or polysemous words (e.g. *get*) were eliminated (Reilly et al., in development). The Subtlex-American English word frequency norms were used to eliminated words with a lexical frequency cut-off below five-per-million (Brysbaert & New, 2009; Reilly et al., in development). Translationally equivalent Spanish words with a lexical frequency difference greater than ±1 standard deviation from English lexical frequency were eliminated using data from the Subtlex-Esp Spanish database (Cuetos, Glez-Nosti, Barbón, & Brysbaert, 2011; Reilly et al., in development).

Data Collection Procedures

Two bilingual graduate student research assistants conducted experimental testing in two sessions, each spaced approximately one week apart. For bilingual participants, language order was counterbalanced, with one session administered only in English and one session administered only in Spanish. Monolingual control participants rated the same 80 nouns twice in English during two sessions spaced one week apart. During each session, participants were seated in front of a computer in a quiet room while an examiner sat behind a partition to administer the experiment. All participants rated the same 80 nouns (or their translational equivalents in Spanish) according to six semantic dimensions (color, sound, morality, polarity, quantity, and place) via a 7-point Likert scale. Likert scale anchors ranged from the lowest rating of 1 point ("None"/"Ninguno") to the highest rating of 7 points ("Strong"/"Fuerte") with a midpoint rating of 4 points ("Some"/"Alguno"). Qualtrics software was used to present and record stimuli. Each semantic dimension (i.e., color) was presented in its own block, with each of the 80 nouns randomized within this block. Participants rated all items within one block (e.g., "Rate the extent to which this word evokes a strong sense of color") prior to moving on to the next block (Reilly et al., in development). For a full list of Spanish and English experimental instructions, please see Appendix A. No time limit was imposed.

Language Proficiency and Dominance Measures

Assessing Language Dominance through the Bilingual Language Profile.

All bilingual participants were asked to complete the *Bilingual Language Profile* (BLP) as a measure of language dominance (Birdsong et al., 2012). The BLP consists of four main sections: Language History, Language Use, Language Proficiency, and Language Attitudes (Birdsong et al., 2012). Each of these sections consists of self-rated questions using a Likert scale to facilitate scaled answers (Birdsong et al., 2012). To provide a full picture of language history, use, proficiency, and attitude in each languages spoken by the bilingual individual, participants are asked to answer every question in regards to each language spoken. All question items receive the same weight during scoring (Birdsong et al., 2012), and individual scores are generated for each section (referred to as “Module Scores”). Each language spoken by the participant receives a “Global Score”, which is calculated by adding together each module score. Each language can receive a maximum global score of 218 points. Finally, a “Global Dominance Score” is calculated by subtracting one language’s global score from the global score of a participant’s second language. Dominance scores can range from -218 to +218 points, with a score near 0 indicating balanced bilingualism (Birdsong et al., 2012).

The BLP has been validated against many other standardized measures of language proficiency and dominance (Birdsong et al., 2012). In Gertken, Birdsong, & Amengual (2012), English-French bilinguals (n=65) completed the Oxford Placement Test in French. Their proficiency scores from this examination were correlated with self-reported scores on the Language Proficiency module of the BLP. Self-reported proficiency measures on the BLP demonstrated a significant correlation ($r=0.63$, $p <.01$) with proficiency scores earned on the Oxford Placement Test (Gertken et al., 2012). Differences in language dominance as found in the BLP Global Dominance Score were compared to reaction time differences during completion of *A Quick Test of Cognitive Speed* (Gertken et al., 2012; Wiig et al, 2002). Of the selected English-French bilinguals, a smaller group (n=47) completed *A Quick Test of Cognitive Speed (AQT)* in both French and English. The language dominance score assigned by the AQT was found to correlate significantly to with the Global Dominance Score proposed by the BLP ($r=.41$, $p <.01$) (Gertken et al., 2012). When compared to reaction time measures in a sentence judgment task undertaken in French, BLP Global Dominance Scores yet again correlated significantly ($r=.37$, $p <.01$) with reaction times for agent vs. patient decisions in complicated sentences (Gertken et al., 2012). Due to these high levels of validity with other standardized measures, the BLP was selected as a primary measure of language dominance for this study (Birdsong et al., 2012).

Proficiency Measures.

Although language proficiency skills are not the focus of this study, limited proficiency measures were collected. Following the rating of 80 nouns, each participant was asked to complete proficiency tasks including a 60-item Boston Naming Test (BNT) in both English and Spanish (Kaplan, Goodglass, & Weintraub, 1983), a verbal fluency task in both English and Spanish, and a word association task in both English and Spanish. As with semantic rating assignments, monolingual participants completed the same proficiency measures in English over two consecutive sessions spaced one week apart.

Participants completed a computerized version of the Boston Naming Test (Kaplan et al., 1983). Each person was asked to verbally name each of 60 black-and-white picture items displayed using E-Prime 2.0 professional software (Psychology Software Tools, Pittsburgh, PA) with a 6000 ms inter-trial interval (Reilly et al., in development). Each session of the BNT was conducted either only Spanish or only English, and each administration was spaced one week apart. Responses were recorded using a digital audio recorder and were transcribed and scored separately. A naming difference score for each participant (English Naming Proficiency-Spanish Naming Proficiency) was calculated and compared to each participant's BLP dominance score using a bivariate correlation (Birdsong et al., 2012; Reilly et al., in development).

Participants also completed a verbal fluency task and a word association task using E-Prime 2.0 professional software (Psychology Software Tools, Pittsburgh, PA). During the verbal fluency task, the participant was asked to name as many words as he/she could think of that began with a target letter (e.g. “A”) or that belonged to a target category (e.g. “Fruits and Vegetables”). Six trials were completed, and the participant was given 60 seconds to name as many words as possible in each trial. During the word association task, participants were presented with each test item (80 words total) and asked to name the first word that came to mind (excluding synonyms). Participants were given 5 seconds to complete each trial. As in the BNT task, responses were recorded via audio and scored at a later date.

CHAPTER 4

METHODS OF ANALYSIS

Variables of interest for the current study include: 1) Semantic ratings of 80 nouns made by English-dominant bilingual individuals in English; 2) Semantic ratings of 80 nouns made by English-dominant bilingual individuals in Spanish; 3) Semantic ratings of 80 nouns made by Spanish-dominant bilinguals in English; 4) Semantic ratings of 80 nouns made by Spanish-dominant bilinguals in Spanish; 5) Semantic ratings of 80 nouns made by monolingual English-speaking individuals at Time 1; 6) *Bilingual Language Profile* results for all bilingual participants (Birdsong et al., 2012). Bilingual participant ratings of 80 translationally equivalent nouns across six different semantic dimensions (sound, color, emotional valence, polarity, size, and distance) in English will be compared to the semantic ratings of the same 80 nouns completed by monolingual English-speaking peers. Semantic ratings produced by English monolingual participants at Time 1 and Time 2 were found to be nearly identical, with a Mantel statistic correlation of ($r=0.91$, $p<.001$). To eliminate possible practice effects, however, semantic ratings produced by English monolingual participants at Time 2 were not considered in this study.

Table 1

Study variables separated by dominance score and language condition.

Dominance Condition	Bilinguals rating English	Bilinguals rating Spanish	English Monolinguals
English-dominant	English-dominant bilinguals rating in English	English-dominant bilinguals rating in Spanish	English monolinguals rating at Time 1
Spanish-dominant	Spanish-dominant bilinguals rating in English	Spanish-dominant bilinguals rating in Spanish	

The BLP Global Dominance Scores of bilingual participants were used to separate bilinguals into English-dominant and Spanish-dominant groups according to the parameters put forth in assessment's instructions for scoring (Birdsong et al., 2012). To obtain a Global Dominance Score, each participant's Global Spanish Score was subtracted from his/her own Global English Score. English-dominant bilinguals (n=11) achieved Global Dominance Scores greater than zero, while Spanish-dominant bilinguals (n=9) achieved Global Dominance Scores of less than zero. No participants achieved a perfectly "balanced" score of zero. Raw semantic ratings across all six semantic categories (color, sound, morality, position, size, quantity) were compiled for each test item. Raw semantic ratings were converted into Euclidean distance matrices using complete linkage, combining all six semantic ratings for each test item. Euclidean semantic distance matrices were created for 1) Monolingual English speakers rating English at Time 1; 2) English-dominant bilinguals rating English; 3) English-dominant bilinguals rating Spanish; 4) Spanish-dominant bilinguals rating English; and 5) Spanish-dominant bilinguals rating Spanish.

K-means partitioning was applied to all raw semantic ratings separated by language dominance (English-dominant bilingual, Spanish-dominant bilingual, or Monolingual) and language use (Spanish or English) condition using the "Nbclust" (distance=Euclidean, index=all) package in R (Charrad, Ghazzali, Boiteau, & Niknafs, 2015). "Nbclust" analyzes the optimal clustering configuration based on 26 different k-means clustering indices. The elbow plot method was used as an alternate clustering analysis method in cases where Nbclust suggested two equally plausible clustering configurations.

Five semantic tree dendrograms were created using hierarchical cluster analysis: one semantic tree dendrogram for each of the five participant conditions. Each dendrogram was formed based on the results of K-means clustering. Each Euclidean semantic distance matrix was compared between groups using a Mantel Test correlation (Quantitative Insights into Microbial Ecology, n.d.). A Spearman correlation was used to compare average semantic ratings across all six semantic dimensions (color, sound, morality, valence, size, position) for all test items within each participant conditions. To gather more information about the distribution of test items across participant conditions, each test item was categorically coded as a/an 1) social construct; 2) animate object; 3) tool; 4) imageable object; or 5) natural kind. Cluster distributions of these semantically-coded test items were analyzed using chi-squared tests of independence between k-cluster and semantic category, applying a Bonferroni correction for multiple comparisons (n=15, α corrected =.003, as seen in Reilly et al., in development).

Reliability

Prior to data analysis, all raw data containing participants' semantic ratings was downloaded from password-protected Qualtrics account and stored on a secure server. Two volunteers independently transposed, alphabetized, and pasted this raw data into a new spreadsheet. Both spreadsheets were compared for discrepancies. Reliability was calculated to be 99.4% for all semantic ratings. Discrepancies between both spreadsheets were settled by 100% agreement from two independent reviewers (authors HF and AK). These reviewers also independently re-transposed, alphabetized, and copied semantic ratings made in Spanish by bilingual participants from the main Qualtrics account with 100% agreement. Bilingual participants' Global Language and Global Dominance scores were independently calculated by two reviewers (author HF and co-worker AK). Both reviewers calculated scores with 98.6% agreement. Discrepancies were settled by group consensus. Reliability ratings were calculated by dividing the number of agreements by total scores calculated.

CHAPTER 5

RESULTS

Dendrograms

To determine the most closely-fitting clustering pattern for the semantic ratings data, K-means clustering in the Nbclust package (Charrad et al., 2015) using ‘all’ indices was applied. The Nbclust package ‘all’ uses 26 available k-means clustering indices, then applies the common rule to recommend the clustering pattern supported by the largest number of indices (Charrad et al, 2015). The Nbclust package recommended three clusters as the best way to group raw semantic ratings in all five participant conditions. Because of this, all five semantic tree dendrograms were ‘cut’ into three branches. Each branch was filled in with a different color to maximize visual contrast. The Euclidean distance formula was applied to semantic ratings in each of the five participant conditions to create five tree dendrograms. Despite the fact that all semantic tree dendrograms have three main branches, individual stimuli showed different clustering patterns in each participant condition. Full results for all dendrograms can be found in Appendix C.

Mantel Tests

To provide an over-arching idea of semantic tree dendrogram correlation, a Mantel test was conducted on the Euclidean distance matrices for all five participant conditions. Comparing Euclidean distance matrices among participants in the same language dominance condition revealed high levels of similarity between both English-dominant and Spanish-dominant participants. English-dominant participants rating in English showed high levels of matrix similarity to their own semantic ratings in Spanish

($r = 0.875$, $p < .001$). Spanish-dominant participants rating English also showed high levels of matrix similarity to their own semantic ratings in Spanish ($r = 0.880$, $p < .001$). When comparing across language dominance conditions, Mantel test results were slightly lower. Euclidean distance matrices from English-dominant bilinguals rating English and Spanish-dominant bilinguals rating English were found to have a Mantel statistic of ($r = .835$, $p < 0.001$). English-dominant bilinguals rating Spanish showed slightly lower Mantel statistic ($r = 0.823$, $p < 0.001$) to the Euclidean distance matrix created from Spanish-dominant bilinguals rating Spanish. Finally, comparisons within bilingual speakers crossing both language use and dominance conditions were obtained. English-dominant bilinguals rating English showed a Mantel statistic of ($r = .822$, $p < 0.001$) when compared to Spanish-dominant bilinguals rating Spanish. English-dominant bilinguals rating Spanish, showed a Mantel statistic of ($r = .815$, $p < 0.001$) to Spanish-dominant bilinguals ratings English. Mantel correlations across both language use and dominance conditions were only slightly lower than the Mantel correlations obtained across dominance conditions.

To examine possible effects of language use, language dominance, and linguistic status on semantic rating performance, Euclidean distance matrices of English monolinguals were compared to those of both English-dominant bilinguals rating in Spanish ($r = .795$, $p < 0.001$), and Spanish-dominant bilinguals rating in Spanish ($r = .790$, $p < 0.001$). When compared to English Monolingual speakers rating at Time 1, English-dominant bilinguals rating in English showed a Mantel statistic of ($r = 0.849$, $p < 0.001$) while Spanish-dominant bilinguals rating English showed a similar Mantel statistic of ($r = 0.835$, $p < 0.001$).

Table 2

Mantel Test Results

	English Monolingual Time 1	English-Dominant Bilinguals (English)	Spanish-Dominant Bilinguals (English)	English-Dominant Bilinguals (Spanish)	Spanish-Dominant Bilinguals (Spanish)
English Monolingual Time 1	**X**	r=0.849, p<0.001	r=0.835, p<0.001	r=.795, p<0.001	r=.790, p<0.001
English-Dominant Bilinguals (English)	r=0.849, p<0.001	**X**	r=.835, p<0.001	r= 0.875, p<.001	r=.822, p<0.001
Spanish-Dominant Bilinguals (English)	r=0.835, p<0.001	r=.835, p<0.001	**X**	r=.815, p<0.001	r=0.880, p<.001
English-Dominant Bilinguals (Spanish)	r=.795, p<0.001	r= 0.875, p<.001	r=.815, p<0.001	**X**	r=0.823, p<0.001
Spanish-Dominant Bilinguals (Spanish)	r=.790, p<0.001	r=.822, p<0.001	r=0.880, p<.001	r=0.823, p<0.001	**X**

In summary, English-dominant bilinguals showed a high, but not perfect, Mantel correlation (r=.875, p<0.001) to their own ratings in Spanish. Similar results were seen in Spanish-dominant bilinguals rating between languages (r=0.880, p<0.001). These very high correlations within same-dominance groups could point to an effect of language dominance in semantic structuring. When compared to English Monolingual speakers rating at Time 1, English-dominant bilinguals rating English (r=0.849, p<0.001) and Spanish-dominant bilinguals rating English (r=0.835, p<0.001) showed very similar Mantel statistics. There is insufficient evidence to determine whether English dominance creates a semantic space in English-dominant bilinguals that is more similar to that of an English monolingual speaker.

Spearman Correlations

To learn more about semantic ratings for each test item in each specific semantic category (color, sound, morality, valence, size, and position), Spearman correlations were conducted on Euclidean distance matrices produced across all five participant conditions. Spearman correlations focused on cross-language comparisons within same-dominance groups, cross-dominance group comparisons on same-language semantic ratings, and comparison of English semantic ratings between monolinguals and English-dominant bilinguals.

Semantic ratings completed by Spanish-dominant bilinguals in both language conditions showed high correlations among all semantic variables. Semantic ratings of color showed the highest correlation among all test items (0.95). Ratings of sound (0.89), morality (0.89), valence (0.88), and position (0.86) were also very high, with semantic ratings of size showed the lowest correlation at (0.71). When comparing semantic ratings of English-dominant bilinguals rating in both English and Spanish, a similar pattern emerged. English-dominant participants also showed very high correlations (0.92) when rating color among test items in both English and Spanish. Ratings of sound (0.87), morality (0.86), valence (0.83), and position (0.78) were also highly correlated. Semantic ratings of size among test items in both languages showed the lowest correlation (0.57).

Table 3

Spanish Dominant Bilinguals Rating in English vs. Rating in Spanish

Spanish Dominant Bilinguals (Spanish)

Spanish Dominant Bilinguals (English)

	Color	Sound	Morality	Valence	Size	Position
Color	0.95	0.34	-0.63	-0.29	0.36	0.57
Sound	0.41	0.89	-0.23	-0.04	0.29	0.41
Morality	-0.61	-0.09	0.89	0.71	-0.01	-0.47
Valence	-0.32	0.1	0.69	0.88	0.17	-0.3
Size	0.12	0.27	0.13	0.34	0.71	0.3
Position	0.47	0.29	-0.4	-0.18	0.45	0.86

Table 4

English Dominant Bilinguals Rating in English vs. Rating in Spanish

English Dominant Bilinguals (Spanish)

English Dominant Bilinguals (English)

	Color	Sound	Morality	Valence	Size	Position
Color	0.92	0.37	-0.61	-0.34	0.06	0.42
Sound	0.54	0.87	-0.4	-0.38	-0.03	0.35
Morality	-0.65	-0.39	0.86	0.73	0.14	-0.37
Valence	-0.43	-0.37	0.77	0.83	0.13	-0.29
Size	0.29	0.13	-0.27	-0.1	0.57	0.42
Position	0.53	0.36	-0.54	-0.44	0.16	0.78

To determine whether testing language had more of an effect on semantic ratings than dominance condition, the English semantic ratings of both Spanish-dominant bilinguals and English-dominant bilinguals were compared using a Spearman correlation. Semantic ratings of color were highly correlated among test items (0.92). Subjective emotional ratings for morality (0.88) and valence (0.84) were also highly correlated, as were ratings of objective physical qualities such as sound (0.79) and position (0.79). Interestingly, semantic ratings of size showed the lowest correlation (0.65).

This pattern was shown to be even more dramatic when the ratings of English-dominant and Spanish-dominant bilinguals completing semantic ratings in Spanish were compared. Semantic ratings of color were correlated at (0.90), slightly lower than in the English language condition. Sound (0.82), morality (0.86), and valence (0.80) are still highly correlated when rating test items in Spanish, but to a lesser degree. Semantic features of size and position showed much lower correlations; ratings of position showed a (0.68) correlation between English and Spanish-dominant groups, while ratings of size showed a correlation of (0.49). This shows that semantic ratings of size differed among English and Spanish-dominant bilinguals depending on the testing language.

Table 5

English Dominant Bilinguals vs. Spanish Dominant Bilinguals Rating in English

Spanish Dominant Bilinguals (English)

English Dominant Bilinguals (English)

	Color	Sound	Morality	Valence	Size	Position
Color	0.92	0.38	-0.62	-0.27	0.34	0.53
Sound	0.45	0.79	-0.34	-0.17	0.2	0.34
Morality	-0.69	-0.14	0.88	0.66	-0.13	-0.5
Valence	-0.41	-0.05	0.81	0.84	0.17	-0.32
Size	0.04	0.21	0.17	0.35	0.65	0.29
Position	0.4	0.2	-0.39	-0.2	0.44	0.79

Table 6

English Dominant Bilinguals vs. Spanish Dominant Bilinguals rating in Spanish

Spanish Dominant Bilinguals (Spanish)

English Dominant Bilinguals (Spanish)

	Color	Sound	Morality	Valence	Size	Position
Color	0.9	0.41	-0.51	-0.28	0.14	0.47
Sound	0.49	0.82	-0.35	-0.31	0.07	0.39
Morality	-0.66	-0.28	0.86	0.67	0.13	-0.34
Valence	-0.45	-0.2	0.82	0.8	0.1	-0.31
Size	0.3	0.26	-0.19	-0.09	0.49	0.48
Position	0.52	0.37	-0.51	-0.39	0.18	0.68

Finally, Spearman correlations by semantic category were completed using semantic ratings of English Monolinguals completing testing at Time 1. English-dominant bilinguals rating in English showed semantic ratings that were highly correlated with English Monolinguals across all six categories: color (0.91), sound (0.9), morality (0.88), valence (0.86), size (0.77), and position (0.71). Ratings of size were more highly correlated than in any other conditional comparison. When compared to English Monolinguals, Spanish-dominant bilinguals rating in English also showed high correlations in semantic categories related to color (0.93), morality (0.9), and valence (0.88). Semantic properties such as sound (0.83), size (0.69), and position (0.64) were less highly correlated.

Table 7

English Monolingual Time 1 vs. Spanish Dominant Bilinguals Rating in English

Spanish Dominant Bilinguals (English)

Monolingual Time 1	Color	Sound	Morality	Valence	Size	Position
Color	0.93	0.38	-0.63	-0.21	0.05	0.13
Sound	0.38	0.83	-0.12	0.08	0.19	0.07
Morality	-0.54	-0.25	0.9	0.68	0.28	-0.1
Valence	-0.19	-0.07	0.76	0.88	0.55	0.04
Size	0.38	0.19	-0.05	0.23	0.69	0.4
Position	0.52	0.27	-0.48	-0.3	0.21	0.64

Table 8

Monolingual Time 1 vs. English Dominant Bilinguals Rating in English

English Dominant Bilinguals (English)

Monolingual Time 1	Color	Sound	Morality	Valence	Size	Position
Color	0.91	0.42	-0.62	-0.2	0.04	0.13
Sound	0.41	0.9	-0.38	-0.23	-0.05	0.14
Morality	-0.59	-0.29	0.88	0.61	0.21	-0.06
Valence	-0.34	-0.21	0.81	0.86	0.45	0.05
Size	0.11	0.14	0.16	0.34	0.77	0.34
Position	0.39	0.25	-0.37	-0.21	0.21	0.71

In summary, English-dominant bilinguals and Spanish-dominant bilinguals both showed very high correlations to their own semantic ratings in each language condition.

English-dominant bilinguals showed semantic ratings that were highly correlated with English Monolinguals across all six semantic categories. Spanish-dominant bilinguals showed semantic ratings that were highly correlated with English monolinguals in the dimensions of color, morality, and valence with slightly lower correlations for properties such as sound, size, and position. The reason for these differences in correlation among semantic dimensions is not entirely clear. However, it has been posited that properties such as size, quantity, and position may require access to stored semantic information (Henik & Tzelgov, 1982). It is therefore possible that differences in underlying semantic representations of numeracy, abstract size concepts (i.e. large vs. small), and positionality (i.e. in, on, above, below) are manifested in lower correlations for size and position ratings across all conditions.

Kmeans and Cluster Analysis

The distribution of test items within each semantic matrix was analyzed based on K-means clustering results. K-means clustering places items with similar semantic ratings together in a 'cluster' based on the closest possible centroid point (Trevino, 2017). In this study, test items were clustered based on each test item's semantic ratings. All 80 test items were grouped by categorically coding each test word salience as a/an 1) social construct; 2) animate object; 3) tool; 4) imageable object; or 5) natural kind. Qualitative analysis of clustering among test items shows which test items were rated similarly by participants. If test items within the same categorically coded group (i.e. tools) receive similar semantic ratings, this provides insight into perception of common elements among test items. A visual representation of these results can be found in Table 8.

English-dominant bilinguals rating in English showed significant clustering effects based on semantic category codes of social construct, tool, imageable objects, and natural kind. Test items coded as social constructs were concentrated in cluster #2 (n=25), test items coded as tools were predominantly found in cluster #1 (n=10), items coded as imageable were distributed between both cluster #1 (n=24) and cluster #3 (n=21), while items coded as a natural kind were also distributed predominantly among cluster #1 (n=11) and cluster #3 (n=13). This clustering pattern staying largely the same despite language condition. When rating in Spanish, English-dominant bilinguals showed significant clustering effects in the same categories (social construct, tool, imageable object, and natural kind). In contrast to the English language test condition, social constructs were concentrated in cluster #3 (n=23). Tools were still found in cluster #1 (n=10), showing no change at all from the English language condition. Also as in the English language condition, imageable objects and natural kinds were almost identically distributed between two clusters. Imageable objects were found in cluster #1 (n=26) and in cluster #2 (n=23), while natural kind items were found in cluster #1 (n=14) and cluster #2 (n=13).

Spanish-dominant bilinguals rating in Spanish also showed clustering effects that were significant for test items coded as social constructs, tools, imageable objects, and natural kinds. Social constructs were found mostly in cluster #2 (n=23). Although the other coded categories of tools, imageable objects, and natural kinds showed clustering effects, these effects were smaller than in English-dominant conditions. Test items coded as tools were found in both cluster #1 (n=5) and cluster #3 (n=9). Likewise, imageable objects were clustered almost evenly between cluster #1 (n=25) and cluster #3 (n=22), while natural kinds were split between cluster #1 (n=15) and cluster #3 (n=10). This pattern shows that while Spanish-dominant bilinguals rating in Spanish do show significant clustering trends in the same semantic categories, these clustering trends were less concentrated.

When rating in English, Spanish-dominant bilinguals showed a remarkably different pattern: all semantic coding categories (social construct, animate beings, tools, imageable objects, and natural kinds) demonstrated significant clustering effects. Social constructs were concentrated in cluster #3 (n=22), animate objects were found in cluster #1 (n=16), imageable objects grouped overwhelmingly in cluster #2 (n=35), and natural kinds also showed strong grouping effects in cluster #1 (n=24). The tools category showed a less powerful clustering pattern, and almost evenly grouped between cluster #1 (n=6) and cluster #2 (n=8).

English Monolingual participants at Time 1 showed significant clustering effects for the semantically coded categories of social constructs, tools, imageable objects, and natural kinds. Social constructs were clustered strongly in cluster #3 (n=24) and tools were mostly found in cluster #2 (n=11). Imageable objects were mostly found in cluster #2 (n=29), but were also found in cluster #1 (n=17). Natural kinds were almost evenly distributed between cluster #1 (n=10) and cluster #2 (n=14).

Table 9

Clustering Effects across Semantic Categories

Participant Condition	Social Construct	Animate Object	Tools	Imageable Object	Natural Kind
English Monolingual Time 1	Cluster #3 (n=24)		Cluster #2 (n=11)	Cluster #2 (n=29) Cluster #1 (n=17)	Cluster #1 (n=10) Cluster #2 (n=14)
English Dominant Bilingual (English)	Cluster #2 (n=25)		Cluster #1 (n=10)	Cluster #1 (n=24) Cluster #3 (n=21)	Cluster #1 (n=11) Cluster #3 (n=13)
English Dominant Bilingual (Spanish)	Cluster #3 (n=23)		Cluster #1 (n=10)	Cluster #1 (n=26) Cluster #2 (n=23)	Cluster #1 (n=14) Cluster #2 (n=13)
Spanish Dominant Bilingual (English)	Cluster #3 (n=22)	Cluster #1 (n=16)	Cluster #1 (n=6) Cluster #2 (n=8)	Cluster #2 (n=35)	Cluster #1 (n=24)
Spanish Dominant Bilingual (Spanish)	Cluster #2 (n=23)		Cluster #1 (n=5) Cluster #3 (n=9)	Cluster #1 (n=25) Cluster #3 (n=22)	Cluster #1 (n=15) Cluster #3 (n=10)

In summary, significant clustering effects were seen across all participant conditions for the semantic categories: social construct, tools, imageable object, and natural kind. English-dominant bilinguals demonstrated the same clustering effects as monolingual English speakers when rating objects in both English and Spanish. When rating in their dominant language, Spanish-dominant bilinguals showed the same clustering patterns as English-dominant bilinguals and English monolingual speakers. Spanish-dominant bilinguals, however, showed significant clustering effects across all semantic coding categories when rating objects in their non-dominant language. This shows that, when rating in their non-dominant language, Spanish-dominant bilinguals may have relied more on each test item's group membership to generate semantic ratings.

CHAPTER SIX

DISCUSSION

The purpose of this study was to determine whether language dominance structures the semantic space of a bilingual speaker to more closely match the semantic space of a monolingual speaker of the dominant language. It was predicted that, when rating the same 80 nouns in English across six semantic dimensions, semantic ratings produced by English-dominant bilinguals would correlate more closely than ratings produced by Spanish-dominant bilinguals to the semantic judgment ratings of monolingual English-speaking participants at Time 1. This hypothesis was based off of a moderate one-pattern hypothesis for bilingual semantic representation influenced by dynamic interaction between languages, wherein an individual's dominant language maintains stronger connection weights between individual words and their conceptual referents in the semantic space.

The current study is based on the connectionist framework of language interaction (Malt et al, 2015; Pavlenko, 2009) which found support for a moderate one-pattern hypothesis for bilingual naming and sorting. In the context of this study, a strong one-pattern approach to bilingual semantics would mean that all bilingual individuals would show the exact same results in both English and Spanish. Therefore, a strong one-pattern semantic rating hypothesis would require that bilingual participants have nearly identical semantic ratings of all 80 nouns in both English and Spanish. A full two-pattern hypothesis would dictate that Spanish-English bilinguals show the exact same semantic ratings as English monolinguals when naming in English (Ameel et al, 2005). Neither of these two scenarios are supported by the results of this study.

Bilingual participants, regardless of language dominance, produced semantic ratings in each language condition that were highly similar, but not exactly the same (as required by a strong one-pattern hypothesis). English-dominant bilinguals showed a high, but not perfect, Mantel correlation ($r=.875$, $p<0.001$) to their own ratings in Spanish, and the same is true for Spanish-dominant bilinguals rating between languages ($r=0.880$, $p<0.001$). A two-pattern hypothesis of semantic representation would be supported by very different semantic ratings based solely on language condition. In addition, semantic ratings produced by bilinguals from different dominance conditions in the same language do not correlate as highly as semantic ratings produced in different languages by bilinguals within the same language dominance groups. For example, English-dominant bilinguals rating Spanish showed a Mantel statistic of ($r=0.823$, $p<0.001$) with Spanish-dominant bilinguals rating Spanish. This is surprising when compared to the very high correlation between ratings produced in both English and Spanish by Spanish-dominant bilinguals ($r=0.880$, $p<0.001$). This points to the possibility that language dominance may play a larger role in shaping the bilingual semantic space than does language used during a given task. However, while these findings lends some support to a moderate one-pattern hypothesis of semantic representation, firm conclusions cannot be drawn due to the very similar Mantel statistic results across all conditions.

Some effects of dynamic interconnections between languages, with connection weights determined by language dominance, are supported by this data. English-dominant bilinguals rating in English showed very high correlation with English Monolinguals when rating across all six semantic dimensions (color, sound, morality, valence, size, and position). In fact, correlations between English-dominant bilinguals rating in English and English Monolinguals were greater than or equal to (0.71) across all semantic dimensions. In contrast, Spanish-dominant bilinguals rating in English showed lower correlations in only some areas, such as size (0.69), and position (0.64). Overall, when semantic ratings were compared to English Monolingual speakers rating at Time 1, English-dominant bilinguals rating in English showed more similar ratings across all six semantic dimensions, meaning that conceptual representation of the common nouns tested in this study is likely very similar between these two groups. This lends some support to the hypothesis that bilingual individuals who are English dominant will have a semantic space that more closely resembles the semantic space of English monolingual speakers than will Spanish-dominant bilingual individuals. However, Spearman correlations in all categories and across all participant conditions were uniformly high. Further limitations, including a small sample size, differences in daily patterns of English use, and different patterns of bilingual language acquisition are also present. Due to these limitations, there is insufficient evidence to definitively conclude that English-language dominance in these bilingual participants resulted in semantic connection weight structuring more similar to those of an English monolingual speaker.

Results from Spearman correlation analysis show more specific trends among semantic categories. For example, when compared to English Monolinguals, Spanish-dominant bilinguals rating in English showed high correlations in semantic categories related to color (0.93), morality (0.9), and valence (0.88), while semantic properties such as sound (0.83), size (0.69), and position (0.64) showed slightly lower correlations to the ratings of English monolinguals. The semantic categories of size and position also showed low correlations between English-dominant and Spanish-dominant bilinguals when rating nouns in both Spanish. When rating in English, however, English-dominant and Spanish-dominant bilinguals showed slightly low correlations only the semantic category of size. This raises the possibility that certain semantic properties, such as size, may be more affected by language dominance than others. As previously discussed, research in color perception demonstrates that differences in lexical color names may produce differences in color category perception and color memory (Kay & Kemper, 1984; Özgen & Davies, 2002; Roberson et al., 2005). However, there is also evidence that color naming and categorization are anchored across many world languages by eleven main color points (Kay & Regier, 2003). Therefore, it is not surprising that semantic ratings of color are so highly correlated among bilingual speakers. Properties such as size, quantity, and position, however, often require access to stored semantic information relating to numeracy and other abstract concepts (i.e. large vs. small) (Henik & Tzelgov, 1982). These categories could therefore show greater effects of pre-existing semantic differences.

K-means clustering analysis was used to provide further insight into grouping patterns of semantic ratings of all test items. K-means clustering places items with similar semantic ratings together in a 'cluster' based on the closest possible centroid point (Trevino, 2017). Qualitative analysis of k-means clustering can provide more information about which test items were rated similarly by participants, which provides insight into perception of common elements among test items. K-means clustering demonstrated that all participant conditions showed significant clustering effects for test items coded as social constructs, tools, imageable objects, and natural kinds. It is possible that all participants, regardless of linguistic status, language dominance, or language use, perceive items in each of these categories to share some common conceptual features.

In contrast to the very similar clustering patterns evidenced by all other participant groups, Spanish-dominant bilinguals rating in English showed significant clustering effects for all semantically coded categories, including animate objects. Interestingly, however, test items coded as animate did not show significant clustering effects when Spanish-dominant bilinguals were rating in Spanish. One possible explanation for this could be found in the idea of "shallow processing" (Gertken, 2013). This study found that when assessing complex sentence in their non-dominant language, French-English bilinguals relied primarily on shallow processing cues, including context and basic semantic properties, rather than analyzing the deeper syntactic structure of the complex sentence. Although syntactic analysis does not apply here, it is possible that Spanish-dominant bilinguals in this experiment used broader semantic features (such as animacy) to rate objects, rather than relying on more specific semantic attributes or even personal experiences.

Limitations

Any study that attempts to tackle something as complex as bilingualism will have limitations. Limitations for this study include a small sample size (n=20) of bilingual and monolingual participants. Gender imbalance is evident from the available sample (15f/5m), meaning that generalization of the results may not be possible. In addition, this participant sample contained both sequential and simultaneous bilingual individuals with many different language-learning backgrounds. Language learning sequence could serve as a confounding factor for analyses. Further, the fact that several participants (n=14) had lived in a Spanish-speaking country for longer than one year could also be a confounding factor, as a full immersion experience in a country where Spanish is the official language could affect one's semantic associations and language use. Additionally, some translationally equivalent Spanish stimulus words were found to have additional semantic meanings based on differences in Spanish dialect. In most cases, additional semantic meanings were found to be subordinate, less common alternatives to the main semantic meaning. A full list of stimulus words with alternate semantic meanings, as confirmed by a native Spanish speaker, is included in Appendix D.

Perhaps the most important limitation for this study is the lack of a comparison group of monolingual Spanish speakers. Without a group of monolingual Spanish-speaking individuals, it is not possible to gather a complete picture of how language dominance mediates connection weights in the semantic space.

Finally, in any study that compares bilinguals and monolinguals, it also necessary to bear in mind that language processing tasks may effect bilingual individuals differently than monolinguals, due to the demands of language suppression, attention switching, and executive function required in any language task. In light of this, the current study avoided any reaction time analysis, and did not place time constraints on semantic ratings tasks (Bialystok, Craik, Green, & Gollan, 2009; Slabakova, 2013).

Future Directions

To definitively prove the existence of a moderate one-pattern hypothesis of semantic representation with dynamic connection weights mediated by language dominance, future studies should include a larger sample size, with an approximately age-matched group of Spanish monolingual control participants. Breaking participants into more specific groups based on age and manner of language acquisition prior to analysis should be used if possible to avoid confounding factors that could also be responsible for subtle shifts in an individual's semantic space. More research on this and many other topics within the field of bilingual semantics is needed. A more nuanced understanding of how bilingual people perceive the world is necessary to support both educational and clinical opportunities that acknowledge and respect differences between monolingual and bilingual individuals.

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APPENDIX A. SEMANTIC DIMENSIONS AND SCALE WORDING

Table A.1 *Participant Instructions*

Dimension	Version	Scale instructions
Color	English	Rate the extent to which this word evokes a strong sense of color (i.e., this word's referent has high visual color imagery).
	Spanish	Valore el punto hasta el cual esta palabra evoca un fuerte sentido de color (i.e., el referente de la palabra tiene visualización de color fuerte).
Sound	English	Rate the extent to which this word evokes a strong sense of sound.
	Spanish	Valore el punto hasta el cual esta palabra evoca un fuerte sentido de sonido.
Morality	English	Rate the extent to which this word evokes feelings about morality, rules, or social conventions.
	Spanish	Valore el punto hasta el cual esta palabra evoca sentimientos sobre moralidad, reglas, o convenciones sociales?
Valence	English	Rate the extent to which this word evokes strong positive or negative feelings within myself.
	Spanish	Valore el punto hasta el cual esta palabra evoca sentimientos positivos o negativos en mi.
Size	English	Rate the extent to which this this word evokes thoughts about size, amount, or scope.
	Spanish	Valore el punto hasta el cual esta palabra evoca la idea de tamaño, cantidad, o alcance.
Position	English	Rate the extent to which this word evokes thoughts about position, place, or direction.
	Spanish	Valore el punto hasta el cual esta palabra evoca la idea de posición, lugar, o dirección.

(Reilly et al., in development)

APPENDIX B: PARTICIPANT DEMOGRAPHICS

Table B.1 *Bilingual Participant Demographics*

Subject	**Sex**	**Age**	**Country**	**Age_Span**	**Age_Eng**	**L2_Age**	**Education (Years)**
Span01	M	20	NR	7	0	7	14
Span03	M	30	Mexican, DR	0	3	3	18
Span04	M	22	Venezuela	0	7	7	14
Span05	F	23	NR	0	6	6	14
Span07	M	27	NR	0	1	1	14
Span08	M	22	Mexico	0	7	7	16
Span09	F	20	NR	0	0	0	14
Span10	F	23	Colombia	0	8	8	16
Span11	F	22	NR	0	0	0	16
Span12	F	32	Cuba	0	0	0	21
Span13	F	21	Mexico	0	3	3	16
Span14	F	19	Dominican Republic	0	5	5	16
Span15	F	18	Nicaragua, DR	0	0	0	14
Span16	F	23	Puerto Rico	0	3	3	18
Span17	F	18	NR	12	0	0	14
Span19	F	22	Puerto Rico	0	0	0	16
Span21	F	21	Mexico	0	8	8	16
Span22	F	22	Panama	0	3	3	16
Span23	F	28	Peru	0	20+	20+	16
Span24	F	25	Peru	0	0	0	17

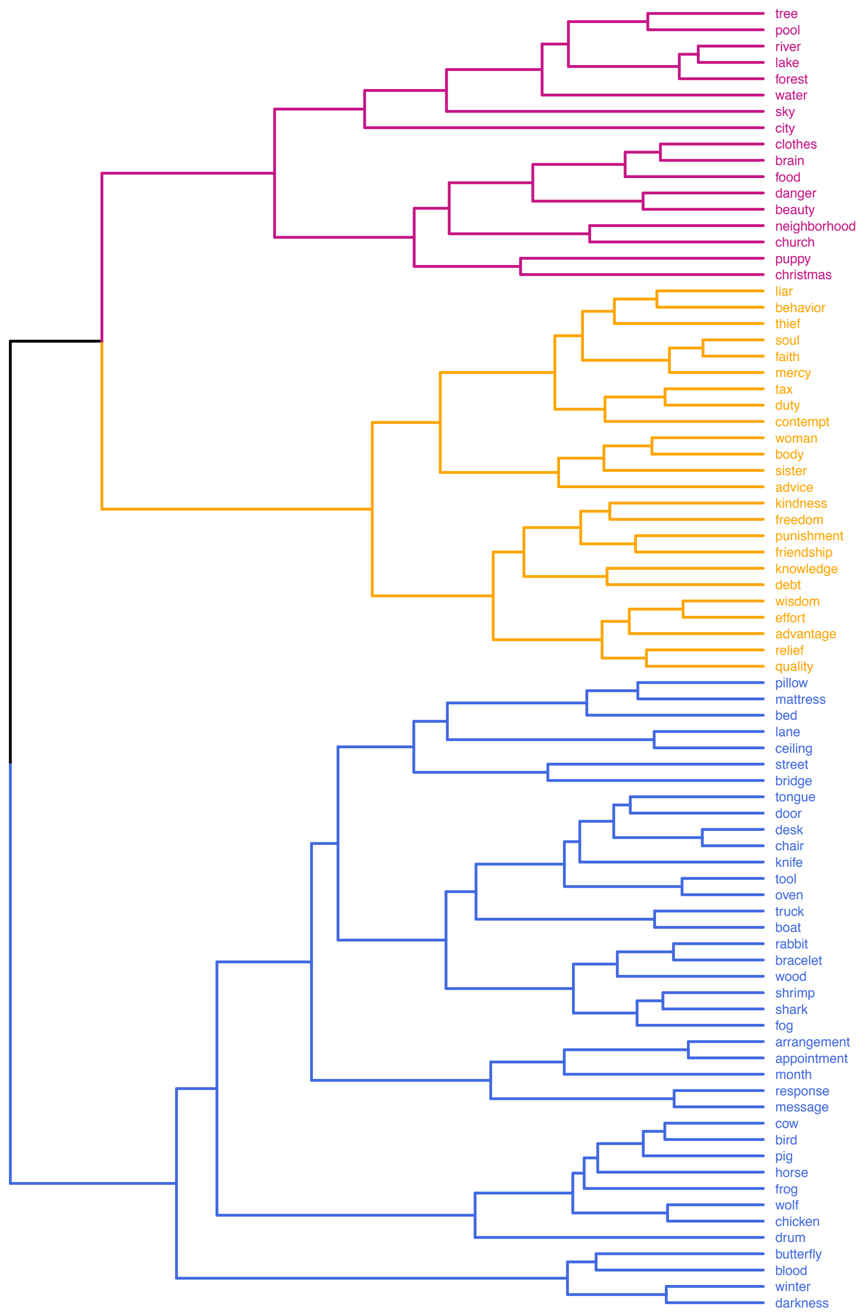
NR= No response
DR=Dominican Republic
Country= Country of greatest Spanish language influence/dialect
Age_Span= Age of Spanish language acquisition
Age_Eng= Age of English acquisition
L2_Age= Age of second language acquisition

Table B.2 *Monolingual Participant Demographics*

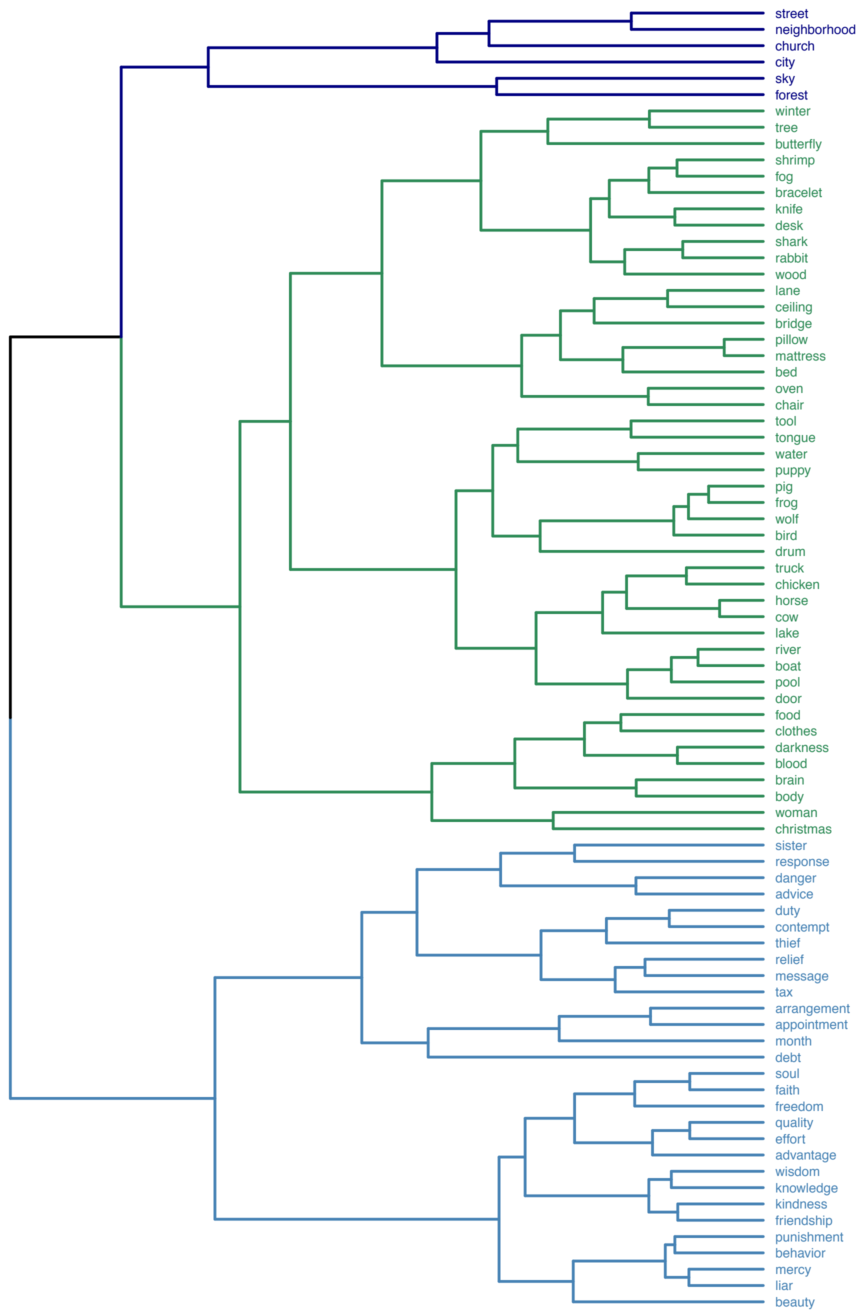
Subject	Sex	Age	Country	Age_Span	Age_Eng	L2_Age	Education (Years)
Eng01	F	21	U.S.A.	N/A	N/A	N/A	14
Eng02	M	20	U.S.A.	N/A	N/A	N/A	14
Eng03	F	20	U.S.A.	N/A	N/A	N/A	14
Eng04	M	23	U.S.A.	N/A	N/A	N/A	16
Eng05	F	22	U.S.A.	N/A	N/A	N/A	14
Eng06	F	21	U.S.A.	N/A	N/A	N/A	14
Eng07	F	23	U.S.A.	N/A	N/A	N/A	16
Eng08	F	26	U.S.A.	N/A	N/A	N/A	14 (2 year degree)
Eng10	M	21	U.S.A.	N/A	N/A	N/A	16
Eng11	F	20	U.S.A.	N/A	N/A	N/A	14
Eng12	F	23	U.S.A.	N/A	N/A	N/A	14
Eng14	F	27	U.S.A.	N/A	N/A	N/A	16
Eng15	F	21	U.S.A.	N/A	N/A	N/A	14
Eng17	F	22	U.S.A.	N/A	N/A	N/A	17
Eng18	F	19	U.S.A.	N/A	N/A	N/A	14
Eng19	F	21	U.S.A.	N/A	N/A	N/A	14
Eng20	M	19	U.S.A.	N/A	N/A	N/A	14
Eng21	F	24	U.S.A.	N/A	N/A	N/A	16
Eng22	F	18	U.S.A.	N/A	N/A	N/A	14
Eng23	M	26	U.S.A.	N/A	N/A	N/A	14

APPENDIX C. DENDROGRAMS BY PARTICIPANT CONDITION

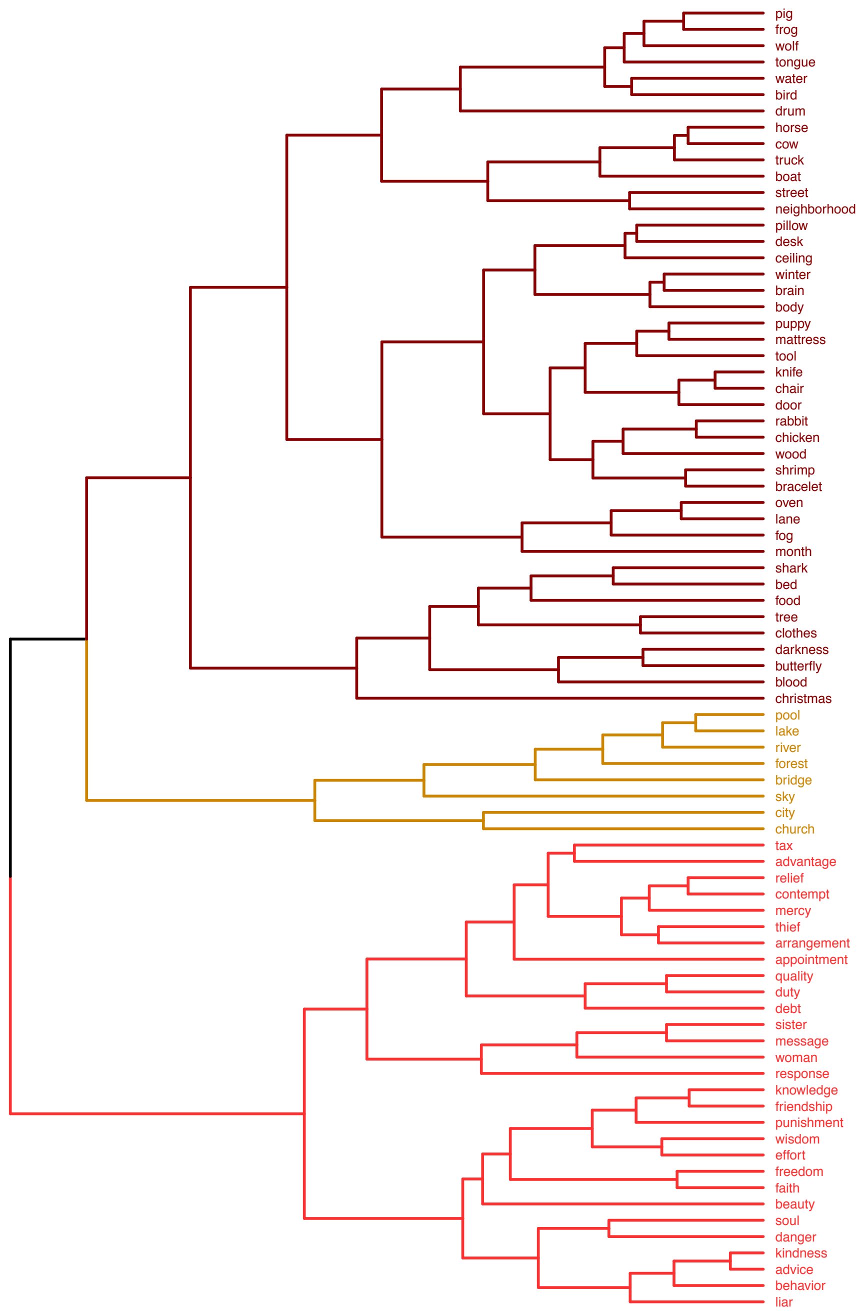
1. English Monolinguals Time 1



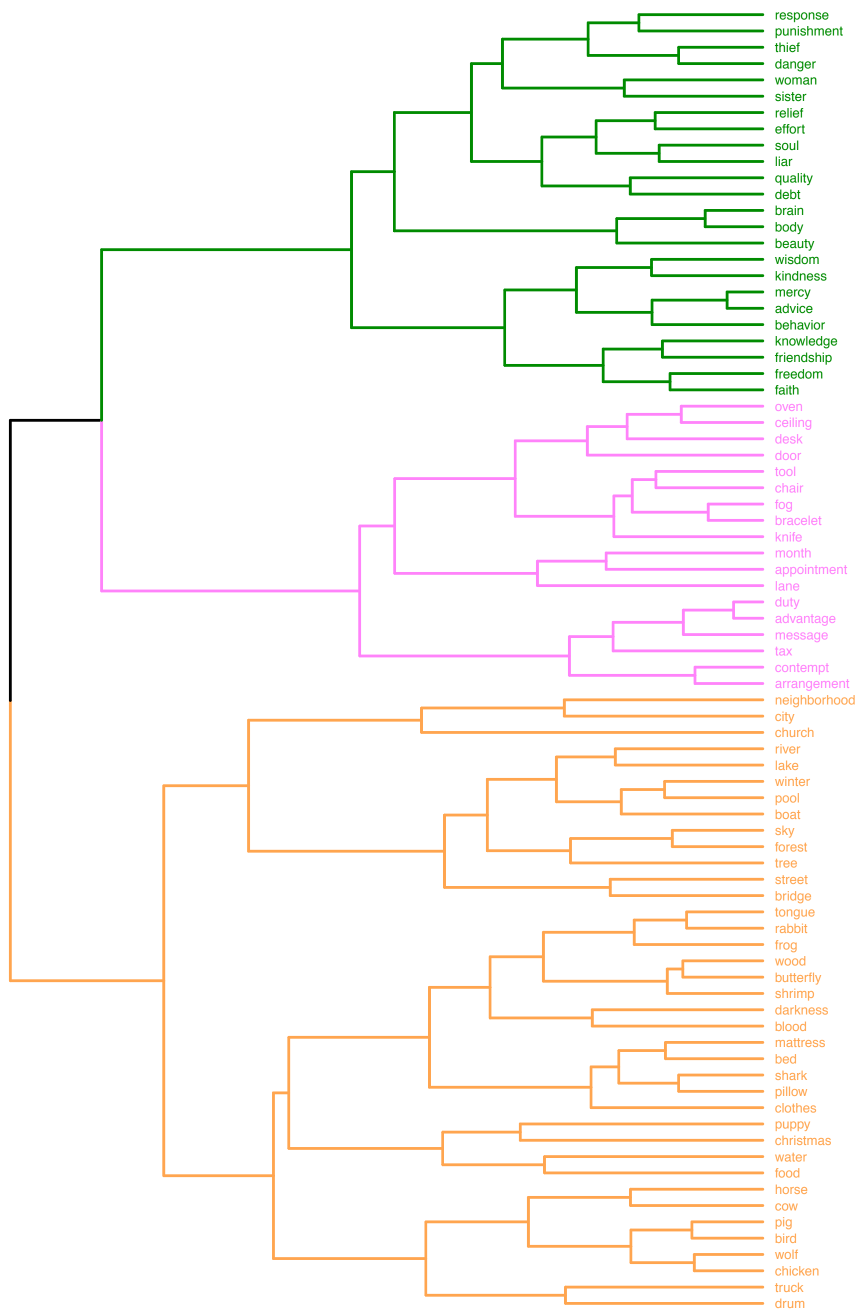
2. English Dominant Bilinguals Rating in English



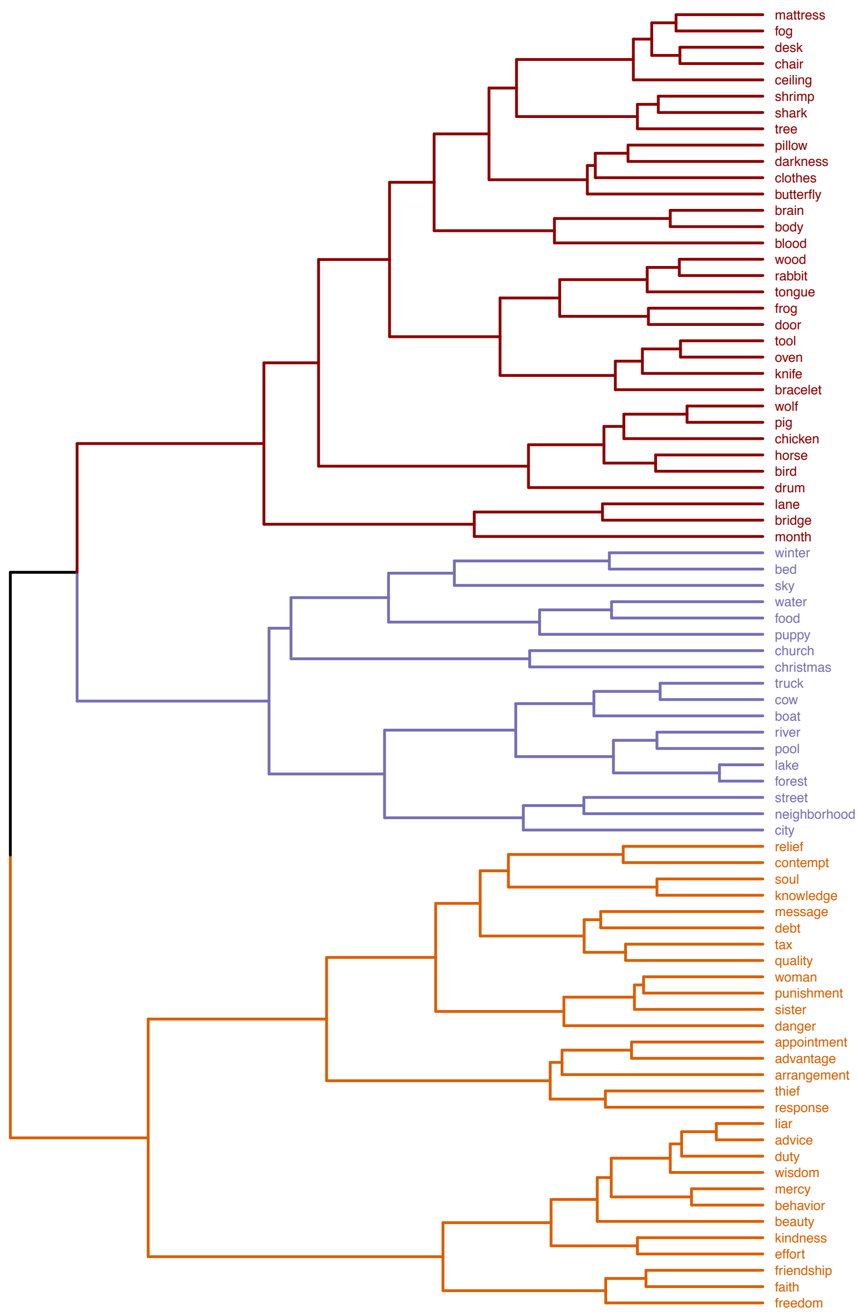
3. English Dominant Bilinguals Rating in Spanish



4. Spanish Dominant Bilinguals Rating in English



5. Spanish Dominant Bilinguals Rating in Spanish



APPENDIX D. ALTERNATIVE MEANINGS OF STIMULUS WORDS

Table D.1 *Alternate Semantic Meanings*

Stimulus Word	**Target Translational Meaning**	**Alternate meaning(s)**
cachorro	puppy	cub, child (informal)
carril	lane	track, rail
cielo	sky	heaven, ceiling
camión	truck	bus
cita	appointment	date, meeting, citation
comportamiento	behavior	performance
deuda	debt	obligation
lengua	tongue	language
impuesto	tax	(adj) something imposed
pájaro	bird	gay man (informal)
pollo	chicken	child (informal)
ventaja	advantage	benefit