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The influence of pre-stroke proficiency on post-stroke lexical semantic performance in bilingual aphasia

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THE INFLUENCE OF PRE-STROKE PROFICIENCY ON POST-STROKE LEXICAL SEMANTIC PERFORMANCE IN BILINGUAL APHASIA

by

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THE INFLUENCE OF PRE-STROKE PROFICIENCY ON POST-STROKE LEXICAL SEMANTIC PERFORMANCE IN BILINGUAL APHASIA

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ABSTRACT

The objectives of this study were to examine if pre-stroke proficiency predicts post-stroke lexical semantic performance in Spanish-English bilingual persons with aphasia (PWA) and identify patterns of impairment in this population. A language use questionnaire was administered to 27 Spanish-English bilingual PWA to measure pre-stroke proficiency in both languages. Standardized language assessments in Spanish and English were administered to measure post-stroke lexical semantic performance in both languages. A principal component analysis was conducted on the language use questionnaire measures, revealing Daily Usage, Education, Exposure, and Language Ability Rating as factors that contribute to a person's proficiency in their first language (L1), and Age of Acquisition, Daily Usage, Family Proficiency, Education, Exposure, Confidence and Language Ability Rating as factors that contribute to a person's proficiency in their second language (L2). Regression analyses revealed that pre-stroke proficiency significantly predicted post-stroke lexical semantic performance, most strongly in English than in Spanish. Two distinct patterns of impairment emerged within the participants: parallel impairment and differential impairment. Overall, these results confirm that pre-stroke language proficiency is a key determiner of performance on standardized language assessments post-stroke, such that the higher proficiency pre-stroke, the higher performance on standardized tests post stroke. This pattern was more clear when English

was L1 or L2 relative to when Spanish was L1 or L2. These results have important implications for assessment and diagnosis of aphasia in bilingual individuals particularly when clinicians need to select the language of assessment.

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I. Introduction

The broad goal of the present project is to determine whether pre-stroke language proficiency predicts post-sroke lexical semantic performance in Spanish-English bilingual persons with aphasia and investigate patterns of impairment in this population.

Statement of the Problem

According to 2011 U.S. Census Data, 21 percent of the population aged 5 and older (60.6 million) spoke a language other than English at home. As a result of migration patterns, and increased globalization, it is likely that the number of bilingual speakers in the United States will continue to grow, and with it, so will the incidence of bilingual aphasia due to stroke, closed head injury, or neurodegenerative disease (Green, 2005). Though such cases are often considered to be an exception or isolated cases, given the sheer number of bilinguals in the world, Fabbro (2001) asserts that bilingual individuals are in fact becoming the majority of clinical cases. Therefore, to provide successful and evidence-based intervention, it is essential that we understand the role of pre-stroke language proficiency and patterns of impairment in bilingual persons with aphasia (PWA).

Nevertheless, studies that look at language impairment in bilingual PWA are often case studies. Frequently, such studies do not consider premorbid language as it relates to post-stroke impairment. As Kroll and Tocowicz (2005) note, the age and context in which a person learns L2 may impact the way in which L1 and L2 are represented and accessed in the brain, suggesting that language acquisition, use, and exposure prior to a person's stroke are crucial factors in determining their impairment post-stroke.

Therefore, this study aims to analyze patterns of impairment in 27 Spanish-English bilingual PWA and determine which language factors (e.g. use, exposure) have the most impact in determining post-stroke language profile. This study will do so by examining the relationship between patient responses to a language use questionnaire (Kastenbaum et al., in press) which measures pre-stroke proficiency in Spanish and English and patient performance on the standardized language assessments in both Spanish and English post-stroke.

II. Background

In order to understand impairment in the bilingual brain, it is crucial to establish a model of bilingual language processing. A number of researchers have put forth models in an attempt to explain the manner in which the bilingual lexicon is organized, the manner in which bilinguals recognize words, and finally, the manner in which bilinguals produce words.

Researchers tend to agree that, in the bilingual brain, two languages access a common semantic network. However, different models have been put forth to explain to what degree these shared connections exist and what factors might influence the creation of a shared semantic network.

The Distributed Feature Model, for example, looks to explain the types of connections that exist between words in the bilingual lexicon (van Hell & De Groot, 1998). In studying the time it took for Dutch-English bilinguals to translate words or recognize whether two words were a translation of each other, Van Hell and De Groot

(1998) theorized that the semantic system of bilinguals is shared, but dependent on word class and word type. The authors found quicker reaction times for nouns, concrete words, and cognates, indicating that nouns may have more shared semantic features between L1 and L2 than verbs, that concrete words may have more than abstract words, and that cognates may have more than non-cognates. As a result, it appears that word class and word type is a factor that affects the degree to which L1 and L2 words are connected to each other in a bilinguals' semantic system.

In another attempt to explain the connections between L1 and L2 words in the bilingual lexicon, Kroll and Stewart (1994) developed the Revised Hierarchical Model, examining the ways in which representations vary depending on proficiency of L2. This model maintains that the connections between L1 and L2 are asymmetrical. In early learning of L2, L2 words are more strongly connected to the L1 translation word than to the concept of the word, whereas L1 words are directly connected to the conceptual representation of the word, as evidenced by slower translation from L1 to L2 than L2 to L1 in bilinguals (Kroll & Stewart, 1994). As bilinguals become more proficient, lexical access to L2 is believed to happen increasingly via the concept of the word, and less via translation of the word from L2 to L1. Therefore, the Revised Hierarchical Model suggests that level of proficiency impacts the organization of a bilingual's lexicon.

Yet it appears that word class and proficiency may not be the only factors in determining the connections between L1 and L2. Kroll and Tokowicz (2005) assert that bilingual representation of words is largely dependent on the learning experience of the person, when and in what context L2 was learned, as well as the characteristics of the two languages that may make shared representations more or less likely. Silverberg and Samuel (2004) investigated the impact of age of acquisition on the representation of L1 and L2 in Spanish-English bilinguals, comparing priming effects for early proficient bilinguals to late proficient bilinguals. The results of their study suggest that early L2 learners map L2 words onto their conceptual representation of L1 words. Late L2 learners, on the other hand, do not appear to form a shared conceptual system for both L1 and L2 and instead seem to share representations at the lexical level. The authors suggest that this may be due to the formal environment that is typical for late L2 learning, in which an emphasis on vocabulary may encourage lexical level connections (Silverberg & Samuel, 2004). Therefore, although high proficiency is a factor that may cause L1 and L2 to share conceptual representations as Kroll and Stewart (1994) suggest, age of acquisition may account for cases in which, despite high proficiency, some L2 learners do not have shared connections at the conceptual level. Silverberg and Samuel's model suggests that the age of acquisition of L2 affects the types of connections between L1 and L2.

Given that the bilingual lexicon appears to consist of a shared semantic network, varying in its degree of connections based on the word and the individual's language learning experience, researchers have also attempted to put forth a model of bilingual word recognition. For example, Thomas and Van Heuvan (2005) proposed the Bilingual Interactive Activation Model (BIA) that assumes, like Dijkstra (2005), word recognition is language nonselective. The BIA Model suggests that four hierarchical levels of linguistic representations exist within the mental lexicon (letter features, letters, words, and language tags) which become activated when a word is presented (Thomas & Van Heuvan, 2005). As a letter feature is activated, activation spreads to other connected representations, ultimately activating the language tag which specifies the language of the target word, and inhibits the nontarget language, allowing the target word to become activated.

Dijkstra and Van Heuven (2002) later revised the BIA model, proposing the BIA+ Model which includes phonological and semantic features in the levels of linguistic representations, acknowledging that bilingual word recognition is not only affected by orthographic similarities between words in L1 and L2, but also the phonologic and semantic overlap between words in each language. Therefore, when a bilingual is presented with a word, it appears that possible words from both languages are activated based upon their semantic, phonologic, and orthographic overlap to the target word.

Similar to theories of word recognition in bilinguals, researchers have also debated whether bilingual word production is language selective or language nonselective. Costa (2005) posits that bilingual word production is language nonspecific, in that lexical and sublexical representations of the unintended language are activated alongside representations for the intended language of production. Costa (2005) suggests that when a bilingual person is asked to name a picture, for example, the semantic system activates both lexicons, spreading activation to the lexical representation of the word in L1 and L2 which spreads to the phonological representation of both L1 and L2. In order to ultimately select the word in the target language, Costa (2005) theorizes that either the semantic system activates the intended word more intensely than the word in the unintended language, or that inhibitory processes occur to lower the activation levels of the unintended language.

One such model that describes these inhibitory processes that allows a bilingual to control their language system is the Inhibitory Control Model (IC) (Green, 1998). This model suggests that language schemas, which specify the steps to a particular mental process, exist to activate and inhibit different lemmas and words depending upon the task being performed (Green, 1998). For example, when bilinguals translate a word from L1 to L2, Green posits that they switch from their input L1 schema to their output L2 schema to produce the desired translation word. Such an inhibitory process is crucial in allowing bilinguals to both speak only in their intended language of production with language switching, and to accurately and rapidly translate words, as they must suppress the production of the word in the presented language and retrieve the word in language it is being translated into.

Models of bilingual lexical organization, word production and recognition can provide a framework for understanding potential patterns of impairment in bilingual aphasia. While models such as the BIA model indicate that the degree of lexical coactivation impacts bilingual word production and recognition, work by Silverberg and Samuels (2004) and Kroll and Stewart (1994) have shown that age of acquisition and the degree of proficiency in each language impacts the organization of a bilingual's lexicon and may influence word recognition and production. This has implications for patterns of impairment and assessment of bilingual aphasia. The influence of proficiency and age of acquisition suggests that gathering a comprehensive language history is a crucial component in understanding and assessing bilingual aphasia.

As a means for understanding bilingual aphasia, researchers have historically attempted to categorize profiles of impairment in bilinguals with aphasia. Previous studies have documented four categories of impairment patterns in bilingual aphasia: parallel impairment, differential impairment in which L2 is more impaired than L1, differential impairment in which L1 is more impaired than L2, and selective impairments in both language (Paradis, 2001; Akbari, 2014).

Several studies, for example, have documented differential impairment in bilingual PWA, in which one language in more impaired than the other (Adrover-Roig et al., 2011; Akbari, 2014; Fabbro, 1999; Fabbro 2001). Adrover-Roig et al. (2011) documented a case of a Basque-Spanish man with aphasia who displayed greater impairment in L1 than L2 as compared to his pre-stroke language use, proficiency, and education history. In a study of 20 Friulian-Italian bilingual PWA, Fabbro (2001) found four participants that were more impaired in L2 than L1 and three that were more impaired in L1, again displaying differential impairment in their language abilities post-stroke.

Other studies document selective impairments in both languages. Fabbro (1999), for example, cites a case in which a patient experienced impairment in both languages, such that they exhibited Broca’s aphasia in one language, and Wernicke's in the other. Other cases of selective impairment indicate deficits in each language dependent on word class, including that of a Spanish-English bilingual who in Spanish named nouns better than verbs, but in English named verbs better than nouns (Ansaldo, Saidi, & Ruiz, 2010).

Researchers who have studied bilingual aphasia have also noted cases in which bilingual PWA exhibit pathological language switching (LS) or language mixing (LM), displaying difficulties in inhibiting the language not intended for production (Fabbro, 1999; Ansaldo & Marcotte, 2007; Ansaldo et al., 2008; Ansaldo et al., 2010). In such cases, the patient is unable to inhibit one language, mixing linguistic elements of both L1 and L2 within one sentence. For example, bilingual PWA might intermix English words or morphemes within the context of a sentence in Spanish, even when their conversation partner only speaks Spanish, displaying language mixing behaviors (Ansaldo & Marcotte, 2007). At other moments, they may exhibit language switching, alternating between English and Spanish at the start of different clauses (Ansaldo & Marcotte, 2007; Ansaldo et al., 2010). This may be the result of not only a deficit at the lexical level, resulting in naming impairments in each language, but also a deficit at the control level, resulting in a lack of resources for inhibitory control that modulate which language is spoken when and suppress the non target language (Green, 1998; Ansaldo & Marcotte, 2007; Ansaldo et al., 2010).

Nevertheless, while these studies comment on patients' pre-morbid language use, a comprehensive language history is not discussed. The authors do not quantify a participants' lifetime use of or exposure to L1 and L2 prior to their stroke, critical factors in determining their proficiency in each language prior to their stroke. Given the impact of acquisition and proficiency on the organization of the bilingual lexicon and connections between L1 and L2 (Kroll & Stewart, 1994; Silverberg & Samuels, 2004), knowledge of how well a patient knew and spoke each language prior to their stroke will impact our understanding of their post-stroke impairment profile, and ability to determine whether their impairment is parallel or differential in relation to their pre-stroke abilities.

Some studies have begun to look at the role that pre-stroke language proficiency plays in impairment in bilingual PWA. Tschirren et al. (2011) examined the role of L2 age of acquisition on syntactic impairment in twelve bilinguals with aphasia and found that L1 and L2 aphasia severity scores did not differ in late bilinguals. However, a comprehensive language history was not included in the analysis of the data.

Other studies have incorporated more comprehensive language use questionnaires to examine impairment in bilingual aphasia. Muñoz and Marquardt (2003), for example, conducted a study of four Spanish-English bilingual PWA and examined post-stroke impairment as compared to pre-stroke language abilities in these four individuals. The authors used a language use questionnaire developed by Muñoz, Marquardt, and Copeland (1999) to calculate the percentage of contexts in which English, Spanish, or both languages were spoken, as well as a proficiency self-rating that asked participants to rate their own ability or comfortableness in speaking and listening to each language in a variety of contexts. In measuring and quantifying each participant's pre-stroke language abilities, Muñoz and Marquardt (2003) found three profiles of impairment: parallel decrease of L1 and L2, differential impairment of L1 and L2, and selective impairments in each language. Given that the authors are able to determine the patterns of impairment based upon their pre-stroke language abilities, the authors assert that these findings support "the need to use estimates of proficiency and use to adequately differentiate a language difference from a language impairment" (Muñoz & Marquardt, 2003, pg. 1129).

Muñoz and Marquardt's assertion is further supported by the study conducted by Gray and Kiran (2013) of 19 Spanish-English bilinguals with aphasia, in which participants completed both a language use questionnaire (LUQ) and standardized language assessments. Language profiles that represented premorbid language use patterns were created using a LUQ that measured factors such as L1 and L2 acquisition, years of exposure, confidence, education history, family proficiency, and a rating of their overall ability in both languages. The authors identified two distinct patterns of impairment: those who lost the same amount in both languages and those who lost differing amounts of language in comparison to pre-stroke abilities. They assert, "For the case of bilingualism, the ability to identify post-stroke language impairment rests on pre-stroke language proficiencies" (Gray & Kiran, 2013, pg. 1317).

In studying bilingual aphasia, researchers have also attempted to estimate the incidence of different subprofiles of recovery in bilingual aphasia. Fabbro (1999) estimated that about 40% of bilingual aphasia cases displayed parallel recovery, 32% had better recovery of L1, and 28% had better recovery of L2. Paradis (2001) reported that out of 132 cases, 61% experienced parallel recovery, 18% displayed differential recovery, 9% displayed a mixing of languages inappropriately, 7% showed selective recovery of one languages, and 5% displayed successive recovery. However, these statistics do not display a complete picture of impairment and recovery patterns in bilingual aphasia. As Gray and Kiran (2013) and Muñoz and Marquardt (2003) assert, in order to fully understand impairment and recovery patterns in bilingual aphasia, a comprehensive measure of pre-stroke language abilities must be used in conjunction with post-stroke language assessments.

III. Rationale

Therefore, the present study will investigate the following questions:

1. Does pre-stroke language proficiency predict post-stroke lexical semantic performance in Spanish-English bilingual PWA? What factors (exposure, use, confidence, self-rating of language ability) play the largest role in determining proficiency in each language? We expect to find that there will be relationships between proficiency and post stroke performance. Based on Kastenbaum et al., (in press) and the impact that age of acquisition and proficiency on the organization of the bilingual lexicon (Silverberg & Samuel, 2014; Kroll & Stewart, 1994), we believe that pre-stroke exposure and use of L1 and L2 and age of acquisition will be primary factors that make up a person's language proficiency and these factors will significantly predict post-stroke language performance.
2. What is the nature of language impairment in Spanish-English persons with aphasia? Given the results of Gray & Kiran (2013), we expect to find two distinct profiles of impairment: parallel impairment (i.e. if Spanish was dominant pre-stroke, Spanish remains dominant post stroke) or differential impairment (i.e. if Spanish was dominant pre-stroke, English is dominant post stroke) across our participant population.

IV. Methods

Participants

At the outset of this study, participants included 47 bilingual adults with aphasia who were part of a patient database in the Aphasia Research Laboratory at Boston University. Three participants were eliminated as two were Russian-English bilingual and one was French-English bilingual. Seven participants were eliminated due to incomplete language use questionnaires or having completed old versions of the language use questionnaire which did not include family, education, exposure, or confidence measures. Ten participants were eliminated as a result of missing standardized language assessments (i.e. had not been administered the BNT or BAT).

As a result, participants of this study included 27 Spanish-English bilingual adults between the ages of 29 and 88 (14 female, 13 male, MPO range = 3-171 months; see Table 1). All participants had a primary diagnosis of aphasia subsequent to left hemisphere CVA and were at least 6 months post onset. Participants were not excluded based on type or severity of their aphasia. All patients were speakers of both Spanish and English prior to stroke.

Stimuli

Language use questionnaire. All participants completed a Language Use Questionnaire (LUQ; Kastenbaum et al., in press), as a measure of their language proficiency in English and Spanish pre-stroke (see Appendix A). The questionnaire can be categorized into the following sections: age of acquisition, exposure, confidence, daily usage, family proficiency, educational history, and self-rating of language ability.

Table 1. Demographics

ID	Sex	Age	MPO	L1
P1	M	59	66	English
P2	F	64	152	Spanish
P3	F	58	15	Spanish
P4	M	59	9	Spanish
P5	F	53	8	Spanish
P6	M	53	11	Spanish
P7	F	73	29	Spanish
P8	M	75	50	Spanish
P9	F	85	7	Spanish
P10	F	88	9	Spanish
P11	M	41	3	Spanish
P12	F	41	3	Spanish
P13	M	43	83	Spanish
P14	M	36	171	Spanish
P15	F	77	4	Spanish
P16	F	65	5	Spanish
P17	M	76	12	Spanish
P18	F	33	3	Spanish
P19	M	54	16	Spanish
P20	F	48	6	Spanish
P21	M	31	27	Spanish
P22	M	33	12	English
P23	M	29	42	Spanish
P24	F	51	33	Spanish
P25	M	55	14	English
P26	F	49	17	Spanish
P27	F	52	56	English

Age of Acquisition. Participants were asked the age at which they acquired their second language (L2). If both languages were acquired simultaneously from birth, age of acquisition of L2 was said to be at 0 years.[1]

Exposure. Participants were asked to indicate the percentage that they heard, spoke, and read English and Spanish over the course of their life. Responses were broken into three-year increments, from 0 to 3 years old up to 27 to 30 years old, with the final time slot as "30 and up." Participants either indicated 100% Spanish, 25% English/75% Spanish, 50% in each language, 75% English/25% Spanish, or 100% English. The percentages were averaged across the age increments with a weight adjustment for participants over age 30, resulting in three scores: exposure hearing Spanish and English, exposure speaking Spanish and English, and exposure reading Spanish and English. These scores for hearing, speaking, and reading were then averaged resulting in a lifetime English exposure score and lifetime Spanish

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[1] Two participants (P5, P15) indicated a range as their age of acquisition (i.e.. 3-6 years old). The age at the lower end of this range was chosen as their age of acquisition for statistical purposes.

exposure score.

Confidence. Similar to ranking their exposure in each language, participants indicated their confidence hearing, speaking, and reading Spanish and English over the course of their life. Participants ranked their confidence hearing and speaking in three-year increments, starting at 3 years old through "30 years old and up." They ranked their confidence in reading in three-year increments starting at 6 years old through "30 years old and up." There were five options to indicate confidence in each language for each modality: not confident (0%), 25% confident, 50% confident, 75% confident, and strong confident (100%). The percentages were averaged across the age increments with a weight adjustment for participants over age 30, resulting in three scores for English and three scores for Spanish: confidence in hearing, confidence in speaking, and confidence in reading. These scores for confidence in hearing, speaking, and reading were then averaged resulting in a confidence in English score and confidence in Spanish score.

Daily Use. Participants were also asked to indicate what languages they and their conversation partners spoke on an hourly basis. Usage data was mostly collected for after their stroke. Participants indicated for each hour between the hours of 7am and 11pm whether they spoke English, Spanish, or Both. The same was done for the language of their conversation partners. Responses were separated based on weekday use and weekend use. The percentage of time participants and their partners spent using each language on both weekdays and weekends was calculated, resulting in two scores: total use of English and total use of Spanish.

Family Proficiency. Participants then rated their parents' and siblings' proficiency in Spanish and English using a percentage scale: not confident (0%), 25% confident, 50% confident, 75% confident, strong confident (100%). Participants rated the proficiency of their mother, father, and siblings separately and in each language separately. Average percentages of confidence were calculated for each language for each family member, resulting in one score of overall family proficiency. Scores were reported separately in English and Spanish.

Educational History. Participants also answered questions about their educational history, indicating which language they used at school at each level of education: elementary school, high school, and college, circling 1 (Spanish), 2 (English), or 3 (both). Participants also used this scale to indicate which language they preferred to speak at school at each level, and what language other students spoke at school at each level of education. A percentage of education in each language was calculated to result in a score for education in Spanish and a score for education in English.

Self-Rating of Language Ability. Finally, participants rated their pre-stroke language ability in Spanish and English based upon a 5-point scale, with 1 being non-fluent and 5 being native fluency. They assigned a rating of fluency when speaking in casual conversations, listening in casual conversations, speaking in formal situations, listening in formal situations, reading, and writing in each language. They also assigned themselves a rating of overall fluency in each language pre-stroke. An average score of Spanish language ability and English language ability was then calculated based upon responses.

L1 vs. L2 As a part of the LUQ participants were asked to indicate which language was their first language (L1). The LUQ and standardized language assessment data was then coded as L1 and L2. Four participants' L1 (i.e., P1, P22, P25, and P27) was English. For the remaining 23 participants, L1 was Spanish.

See Table 2 for participants' language use questionnaire scores.

Table 2. LUQ Summary Scores

ID	L2 AOA	L1 Usage	L2 Usage	L1 Family	L2 Family	L1 Edu	L2 Edu	L1 Expo	L2 Expo	L1 Conf	L2 Conf	L1 LAR	L2 LAR
P1	0	0.94	0.06	0.83	0.83	1.00	0.00	0.75	0.25	1.00	0.83	1.00	0.49
P2	21	0.50	0.50	1.00	0.25	1.00	0.00	0.55	0.45	1.00	0.67	1.00	1.00
P3	5	0.42	0.58	0.92	0.83	0.22	0.78	0.37	0.63	0.59	0.78	0.47*	1.00*
P4	0	0.45*		0.92*	0.00*	0.06	0.94	1.00*		0.94*	0.96*	0.67	0.81
P5	3	0.46	0.54	1.00	1.00	0.33	0.67	0.38	0.62	0.94	0.99	0.74	0.94
P6	6	0.45	0.55	1.00	0.67	0.42	0.58	0.34	0.66	0.66	0.96	1.00	1.00
P7	17	1.00	0.00	1.00	0.88	0.75	0.25	0.66	0.34	1.00	0.83	1.00	0.82
P8	28	0.84	0.16	1.00	0.08	1.00	0.00	0.97	0.03	0.51	0.08	1.00	0.10
P9	69	0.70	0.30	1.00	0.00	0.00	0.00	0.95	0.05	1.00	0.00	0.57	0.20
P10	5	0.01	0.99	1.00	1.00	0.00	1.00	0.29	0.71	1.00	1.00	0.74*	1.00*
P11	18	0.71	0.29	1.00	0.17	1.00	0.00	0.90	0.10	1.00	0.11	0.94	0.34
P12	9	0.71	0.29	1.00	0.33	0.78	0.22	0.68	0.32	1.00	0.41	0.94	0.66
P13	19	0.78	0.22	1.00	0.33	1.00	0.00	0.72	0.28	1.00	0.40	0.89	0.89
P14	6	0.34	0.66	1.00	0.67	0.00	1.00	0.26	0.74	1.00	0.81	0.47	1.00
P15	30	0.92	0.08	1.00	0.00	1.00	0.00	0.85	0.15	1.00	0.46*	1.00	0.26
P16	45	0.98	0.02	1.00	0.00	1.00	0.00	0.87	0.13	1.00	0.13	1.00	0.29
P17	40	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.15	1.00	0.45
P18	12	0.54	0.46	0.92	0.67	0.72	0.28	0.71	0.29	1.00	0.52	1.00	0.80
P19	4	0.99	0.01	1.00	0.08	0.50	0.50	0.89	0.11	1.00	1.00	1.00	0.34
P20	5	0.50	0.50	1.00	0.75	0.67	0.33	0.45	0.55	1.00	0.45	1.00	0.80
P21	5	0.15	0.85	0.67	1.00	0.06	0.94	0.29	0.71	0.68	0.93	0.66	1.00
P22	11	1.00	0.00	1.00	0.25	1.00	0.00	0.91	0.09	1.00	0.50	1.00	0.80
P23	15	0.96	0.04	1.00	0.33	0.75	0.25	0.97	0.03	1.00	0.17	1.00	0.67
P24	7	0.50	0.50	1.00	0.67	0.25	0.75	0.23	0.77	0.20	0.96	0.74	1.00
P25	0	0.90	0.10	1.00	0.92	0.33	0.67	0.43	0.57	1.00	1.00	1.00	1.00
P26	12	0.22	0.78	1.00	0.17	0.78	0.22	0.59	0.41	1.00	0.46	0.99	1.00
P27	13	0.89	0.11	1.00	0.67	1.00	0.00	0.71	0.29	1.00	0.90	1.00	0.77

*denotes value imputed by multivariate imputation by chained equations using the MICE package in R

Standardized language assessments. All participants were also administered the following standardized language assessments as measures of their language abilities in both Spanish and English following their stroke. Standardized language assessment data were collected from testing timepoints closest to the date of the participants' most complete Language Use Questionnaire.[2]

The Boston Naming Test. Participants were administered both Spanish and English versions of *The Boston Naming Test (BNT;* Kaplan, Goodglass, & Weintraub, 1983; Kohnert, Hernandez, and Bates, 1999) assessing the client's ability to name to confrontation 60 black and white pictures presented individually in both languages.

Bilingual Aphasia Test. Participants also completed the following subtests of the Spanish and English *Bilingual Aphasia Test* (*BAT;* Paradis, & Ardila, 1989; Paradis, Libben, & Hummel, 1987): semantic categories, synonyms, antonyms, and antonyms II to assess participant's comprehension of spoken words in both languages. A BAT Composite Score was calculated for each participant in each language by averaging the four scores of these subtests.

The Pyramids and Palm Trees Test. Finally, to assess participants' ability to retrieve semantic features of objects and draw associations between related objects, participants completed *The Pyramids and Palm Trees Test* (Howard & Patterson, 1992). Participants were presented with a picture at the top of a page which they had to match to the semantically related picture on the bottom of the page out of a field of two pictures.

[2] Five participants (P1, P2, P3, P22, P27) were determined to have incomplete testing from the time point at which they filled out their Language Use Questionnaire. These participants had completed testing at other timepoints. These data were included in statistical analyses for these participants so as to maintain these participants in the study.

See Table 3 for participants' standardized language assessment scores.

Table 3. Standardized Language Assessment Scores

ID	**L1 BNT**	**L2 BNT**	L1 Sem Cat	L1 Syn	L1 Ant	L1 Ant II	**L1 BAT Comp**	L2 Sem Cat	L2 Syn	L2 Ant	L2 Ant II	**L2 BAT Comp**	**PAPT**
P1	0.35	0.02	0.80	1.00	0.60	0.80	0.80	0.60	0.00	0.40	0.00	0.25	0.83
P2	0.45	0.47	0.80	0.80	1.00	0.80	0.85	0.40	0.60	0.80	0.60	0.60	0.90
P3	0.18	0.42	0.80	0.60	0.60	0.60	0.65	0.80	1.00	1.00	0.40	0.80	0.92
P4	0.00	0.00	0.60*	1.00*	0.00*	0.80*	0.55*	1.00*	1.00*	0.20*	0.80*	0.60*	0.52*
P5	0.05	0.05	1.00	0.40	0.40	0.40	0.55	0.80	1.00	0.40	0.40	0.65	0.98*
P6	0.07	0.52	0.80	0.40	0.60	0.60	0.60	0.60	0.20	0.60	0.60	0.50	0.87
P7	0.32	0.28	0.60	0.60	0.80	1.00	0.75	0.60	0.60	0.60	0.60	0.60	0.77
P8	0.47	0.03	0.60	0.20	0.00	0.40	0.30	0.00	0.00	0.00	0.00	0.00	0.75
P9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71
P10	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
P11	0.47	0.05	1.00	1.00	0.00	0.80	0.70	0.60	0.00	0.00	0.80	0.35	0.83
P12	0.02	0.00	0.60	0.20	0.40	0.80*	0.45*	0.40	0.00	0.40	0.40	0.30	0.90
P13	0.43	0.37	0.60	0.20	0.40	0.60	0.45	0.60	0.40	0.80	0.20	0.50	0.92
P14	0.12	0.42	0.60	0.60	0.40	0.40	0.50	0.80	0.80	0.20	0.40	0.55	0.94
P15	0.20		0.00	0.60	0.40	0.60	0.40	0.00	0.00*	0.80*	1.00*	0.25*	0.52*
P16	0.15	0.00	0.40	0.40	0.80	0.00	0.40	0.00	0.20	0.20	0.60	0.25	0.52
P17	0.42	0.03	0.60	1.00	0.00	0.20	0.45	0.40	0.40	0.00	0.60	0.35	0.73
P18	0.00	0.00	0.80	0.60	0.20	0.60	0.55	0.20	0.60	0.20	0.60	0.40	1.00
P19	0.00	0.00	0.80	0.40	0.20	0.00	0.35	0.20	0.00	0.20	0.60	0.25	0.87
P20	0.63	0.67	1.00	1.00	1.00	0.80	0.95	1.00	1.00	1.00	1.00	1.00	0.98
P21	0.08	0.63	0.80	0.20	0.80	0.20	0.50	1.00	0.80	0.80	0.60	0.80	0.87
P22	0.82	0.25	1.00	1.00	1.00	0.80	0.95	1.00	0.60	1.00	1.00	0.90	0.98
P23	0.18	0.15	0.60	0.60	0.40	0.80	0.60	0.60	0.00	0.00	0.60	0.30	0.63
P24	0.50	0.65	0.80	0.40	0.40	0.60	0.55	0.80	1.00	0.80	0.60	0.80	0.85
P25	0.00	0.00	0.40	0.20	0.60	0.20	0.35	0.20	0.20	0.20	0.20	0.20	0.52
P26	0.70	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.95	1.00
P27	0.97	0.08	1.00	1.00	1.00	0.60	0.90	1.00	0.20	0.40	0.40	0.50	0.96

*denotes value imputed by multivariate imputation by chained equations using the MICE package in R

Statistical Analysis

Of the 27 participants, three participants (i.e. P3, P4, P10) were found to have missing LUQ values. Three participants (i.e. P4, P5, P15) were found to have missing language assessment values. Multivariate imputation by chained equations was completed using the mice package in R to impute missing values with plausible data values using predictive mean matching. This imputed data was individually checked against a participant's values on other variables to ensure that the imputed value was reasonable for each participant's language proficiency or language abilities. See Table 2 and Table 3 for imputed language use questionnaire and standardized language assessment values.

Given the large number of individual data points on the language use questionnaire, a principal component analysis (PCA) was conducted in R to reduce the items on the questionnaire to underlying components that measure the same construct. The PCA was conducted separately for L1 LUQ scores and L2 LUQ scores. Factors with eigenvalues greater than 1 were determined to be principal components. Items with factor loadings greater than 0.5 were said to load onto a particular factor and therefore were determined to be highly correlated with that component. Following each principal component analysis, individual factor loading scores were extracted for each participant for L1 and L2. These factor loading scores were said to represent a participants' proficiency in L1 and L2 prior to their stroke.

Similarly, another PCA was also conducted to reduce the standardized language assessment measures to the underlying components that measure the same construct. The

PCA was conducted separately for L1 scores on the BNT, BAT, and PAPT, and L2 scores on the BNT, BAT, and PAPT. Factors with eigenvalues greater than 1 were determined to be principal components. Items with factor loadings greater than 0.5 were said to load onto a particular factor and therefore were determined to be highly correlated with that component. Following each principal component analysis, individual factor loading scores were extracted for each participant for L1 language assessment measures and L2 language assessment measures. These factor loadings scores were said to represent a participants' language abilities (comprehension, production, and semantic processing) in L1 and L2 following their stroke.

Finally, a linear regression analysis was conducted in R to determine if pre-stroke proficiency predicted participant performance in each language post-stroke. Specifically, utilizing each participant's L1 LUQ and L1 standardized language assessment factor loading scores, a regression was conducted to determine if an individual's L1 proficiency predicted their performance on L1 language assessments. Given that the language of L1 was English for some individuals and Spanish for others, the language of L1 was included as an additional factor for the purposes of these analyses. A linear regression was conducted predicting language assessment scores using proficiency, language of L1 as a categorical variable (i.e. Spanish or English), and their interaction (e.g., When L1 is Spanish, does L1 proficiency predict L1 language assessment scores). Similarly, utilizing each participant's L2 LUQ and L2 standardized language assessment factor loading scores, a regression was conducted to determine if a person's L2 proficiency predicted their performance on L2 language assessments. A linear regression was conducted predicting language assessment scores using proficiency, language of L1 as a categorical variable (i.e. Spanish or English), and their interaction (e.g., When L1 is Spanish, does L2 proficiency predict L2 language assessment scores).

V. Results

Research Question 1: Does pre-stroke language proficiency predict post-stroke lexical semantic performance in Spanish-English bilingual PWA?

The principal component analysis (PCA) of L1 scores on the language use questionnaire revealed one component with an eigenvalue greater than 1 and explained 52.96% of the variance. A scree plot confirmed that only the first component was meaningful. The factor loadings of the components were examined using a varimax normalized factor rotation. An item was said to load onto a particular component if the factor loading was greater than 0.5. As shown in Table 4, the following L1 questionnaire scores loaded onto Component 1: Daily Usage, Education, Exposure, and Language Ability Rating. Family Proficiency and Confidence did not load onto Component 1. Thus, the principal component analysis identified Daily Usage, Education, Exposure, and Language Ability Rating as factors that contribute to a person's proficiency in L1.

Table 4. Principal component analysis component loadings, LUQ L1

LUQ Components, L1	Component 1
L1 Daily Usage	**0.84**
L1 Family	0.45
L1 Education	**0.86**
L1 Exposure	**0.77**
L1 Confidence	0.50
L1 Language Ability Rating	**0.82**
Variance	52.96%

The principal component analysis of L2 scores on the language use questionnaire revealed one component with an eigenvalue greater than 1 and explained 71.14% of the variance. A scree plot confirmed that only the first component was meaningful. The factor loadings of the components were examined using a varimax normalized factor rotation. An item was said to load onto a particular component if the factor loading was greater than 0.5. As shown in Table 5, all L2 questionnaire scores loaded onto Component 1, which are as follows: AOA, Daily Usage, Family Proficiency, Education, Exposure, Confidence and Language Ability Rating. Thus, the principal component analysis identified all components of the LUQ as factors that contribute to a person's proficiency in L2.

Table 5. PCA component loadings, LUQ L2

LUQ Component, L2	Component 1
L2 AOA	**0.78**
L2 Daily Usage	**0.72**
L2 Family Proficiency	**0.82**
L2 Education	**0.86**
L2 Exposure	**0.95**
L2 Confidence	**0.84**
L2 Language Ability Rating	**0.86**
Variance	71.14%

Factor loading scores for L1 and L2 were then derived for each participant from these principal component analyses (see Table 6). These factor loading scores were said to represent their pre-stroke proficiency in each language.[3]

The PCA on L1 standardized language assessment scores (BNT, BAT Composite Score, and PAPT) revealed one component that had an eigenvalue greater than 1 and explained 71.80% of the variance. A scree plot confirmed that only the first component was meaningful. The factor loadings of the components were examined using a varimax normalized factor rotation. An item was said to load onto a particular component if the factor loading was greater than 0.5. As shown in Table 7, all L1 standardized language assessment measures loaded onto Component 1, which are as follows: BNT, BAT Composite, and PAPT.

[3] Factor loading scores for L2 Proficiency could not be generated for P4 due to missing proficiency data and therefore they were not included in the L2 regression analysis.

Table 6. Participants' individual factor loading scores extracted from LUQ PCAs

ID	L1	L1 Proficiency	L2 Proficiency
P1	English	0.58	-0.09
P2	Spanish	0.32	0.03
P3	Spanish	-1.72	1.06
P4	Spanish	-0.66	
P5	Spanish	-0.76	1.14
P6	Spanish	-0.60	0.98
P7	Spanish	0.71	0.11
P8	Spanish	0.64	-1.44
P9	Spanish	-0.46	-1.78
P10	Spanish	-1.45	1.62
P11	Spanish	0.76	-1.02
P12	Spanish	0.40	-0.24
P13	Spanish	0.57	-0.39
P14	Spanish	-1.57	1.21
P15	Spanish	0.98	-1.16
P16	Spanish	1.05	-1.50
P17	Spanish	1.20	-1.46
P18	Spanish	0.15	0.11
P19	Spanish	0.73	-0.37
P20	Spanish	-0.01	0.43
P21	Spanish	-2.30	1.48
P22	English	1.11	-0.60
P23	Spanish	0.96	-0.75
P24	Spanish	-1.50	1.10
P25	English	0.10	0.92
P26	Spanish	-0.07	0.19
P27	English	0.83	-0.04

Table 7. PCA component loadings, standardized language assessments L1

Language Assessments, L1	Component 1
BNT	**0.84**
BAT Composite	**0.91**
PAPT	**0.78**
Variance	71.80%

The principal component analysis on L2 standardized language assessment scores (BNT, BAT Composite Score, and PAPT) revealed one component that had an eigenvalue greater than 1 and explained 74.94% of the variance. A scree plot confirmed that only the first component was meaningful. The factor loadings of the components were examined using a varimax normalized factor rotation. An item was said to load onto a particular component if the factor loading was greater than 0.5. As shown in Table 8, all L2 standardized language assessment measures loaded onto Component 1, which are as follows: BNT, BAT Composite, PAPT.

Table 8. PCA component loadings, standardized language assessments L2

Language Assessments, L2	Component 1
BNT	**0.88**
BAT Composite	**0.93**
PAPT	**0.79**
Variance	74.94%

Individual factor loading scores for L1 and L2 were then extracted for each participant from these principal component analyses (see Table 9). These factor loadings were said to represent an individual's performance (comprehension, production, and semantic processing) in each language post-stroke.[4]

Table 9. Participants' factor loading scores extracted from lang. assessment PCAs

ID	L1	L1 Performance	L2 Performance
P1	English	0.54	-0.58
P2	Spanish	0.93	0.75
P3	Spanish	0.26	1.00
P4	Spanish	-1.02	-0.74
P5	Spanish	0.03	0.36
P6	Spanish	-0.11	0.60
P7	Spanish	0.29	0.20
P8	Spanish	-0.28	-1.07
P9	Spanish	-1.52	-1.20
P10	Spanish	-2.01	-1.65
P11	Spanish	0.54	-0.39
P12	Spanish	-0.34	-0.38
P13	Spanish	0.29	0.49
P14	Spanish	-0.04	0.68
P15	Spanish	-0.99	
P16	Spanish	-1.06	-1.24
P17	Spanish	-0.15	-0.61
P18	Spanish	0.01	-0.04
P19	Spanish	-0.61	-0.53
P20	Spanish	1.52	1.78
P21	Spanish	-0.25	1.20
P22	English	1.78	1.01
P23	Spanish	-0.43	-0.71
P24	Spanish	0.38	1.19
P25	English	-1.35	-1.31
P26	Spanish	1.74	1.94
P27	English	1.86	0.15

[4] Factor loading scores for L2 Performance could not be generated for P15 due to missing standardized language assignment data and therefore they were not included in the L2 regression analysis.

The linear regression analysis to determine if pre-stroke L1 proficiency predicts post-stroke L1 performance on standardized language assessments resulted in a significant best-fit model that explained 33% of the variance when taking into account the language of L1 (English vs. Spanish) (R^2=.33, $F_{(3,23)}$=3.77, p=.025). L1 proficiency independently was a significant predictor of L1 assessment scores (β=3.34, SE=1.17, *t*=2.85, p=0.009). The language of L1 (whether English or Spanish) was not a significant predictor of L1 assessment scores (β=1.37, SE=0.90, *t*=1.52, p=0.14). The interaction between L1 language and pre-stroke L1 proficiency was significant (β= -3.29, SE=1.18, *t*= -2.78, p=0.0106), in that proficiency was more predictive of performance on L1 language assessments in L1 English speakers than L1 Spanish speakers.

The linear regression analysis to determine if pre-stroke L2 proficiency predicted post-stroke L2 performance resulted in a significant best-fit model that explained 38% of the variance when taking into account the language of L2 (R^2=.38, $F_{(3,21)}$=4.2, p=.0175). L2 proficiency independently was a significant predictor of L2 assessment scores (β=-1.44, SE=.77, *t*=-1.87, p=.075*)*. The language of L1 (whether English or Spanish) was not a significant predictor of L2 assessment scores (β=.21, SE=.46, *t*=.46, p=.65). The interaction between L1 language and pre-stroke L2 proficiency was significant (β=1.96, SE=.79, *t*=2.49, p=.0213), indicating that L2 proficiency was a better predictor of L2 language assessment performance in L1 Spanish speakers (L2 English) than L1 English speakers (L2 Spanish).

Research Question 2: What is the nature of language impairment in bilingual PWA?

To analyze patterns of impairment in these patients, an L1 proficiency composite score and L2 proficiency composite score was generated for each participant by averaging participant's values across LUQ variables. These scores were calculated taking into account the factors that were said to load onto the first component from the PCA. As such, an average of L1 Daily Usage, Education, Exposure, and Language Ability Rating was calculated to represent L1 proficiency. An average of Daily Usage, Family Proficiency, Education, Exposure, Confidence and Language Ability Rating was calculated to represent L2 proficiency. An L1 post-stroke performance composite score and L2 post-stroke performance composite score was generated for each participant by averaging participants' scores on the BNT, BAT, and PAPT in L1 and L2.

As seen in Table 10, two distinct profiles of impairment emerged: parallel impairment and differential impairment. Twenty-two participants demonstrated higher performance post-stroke in the language they had higher proficiency in pre-stroke, deemed to be parallel impairment. As such, these participants reflect the same trends in each language even after stroke (i.e. if Spanish was dominant pre-stroke, Spanish remains dominant post-stroke). Three participants demonstrate a differential impairment post-stroke (see Table 10), in that they performed better on language assessments post-stroke in the language that they were less proficient in pre-stroke (i.e. if Spanish was dominant before stroke, English is dominant post stroke).[5]

[5] L2 Proficiency could not be generated for P4 due to missing proficiency data. L2 Performance could not be generated for P15 due to missing standardized language assessment data. Therefore these participants were not included in the impairment patterns analysis.

Table 10. Participants' patterns of impairment

ID	L1	L1 Proficiency	L1 Performance	L2 Proficiency	L2 Performance
P1	English	0.92	0.66	0.41	0.36
P22	English	0.98	0.92	0.27	0.71
P27	English	0.90	0.94	0.46	0.51
P23	Spanish	0.92	0.47	0.25	0.36
P2	Spanish	0.76	0.73	0.48	0.66
P7	Spanish	0.85	0.61	0.52	0.55
P8	Spanish	0.95	0.51	0.08	0.26
P9	Spanish	0.55	0.24	0.09	0.24
P11	Spanish	0.89	0.66	0.17	0.41
P12	Spanish	0.78	0.46	0.37	0.40
P13	Spanish	0.85	0.60	0.35	0.60
P16	Spanish	0.96	0.36	0.10	0.26
P17	Spanish	1.00	0.53	0.10	0.37
P18	Spanish	0.74	0.52	0.50	0.47
P19	Spanish	0.84	0.41	0.34	0.37
P21	Spanish	0.29	0.48	0.91	0.77
P24	Spanish	0.43	0.63	0.77	0.77
P3	Spanish	0.37	0.59	0.77	0.71
P5	Spanish	0.48	0.53	0.79	0.56
P6	Spanish	0.55	0.51	0.74	0.63
P14	Spanish	0.27	0.52	0.81	0.64
P10	Spanish	0.26	0.16	0.95	0.17
P25	English	0.67	0.29	0.71	0.24
P20	Spanish	0.65	0.85	0.56	0.88
P26	Spanish	0.64	0.90	0.51	0.92

VI. Discussion

The overarching goal of this study was to understand the role of pre-stroke proficiency in post-stroke performance on standardized language assessments in Spanish-English bilingual persons with aphasia. The following research questions were addressed: (1)

Does pre-stroke language proficiency predict post-stroke lexical semantic performance in Spanish-English bilingual PWA? What factors (exposure, use, confidence, self-rating of language ability) determine proficiency in each language and how do these factors predict lexical semantic performance in aphasia? (2) What is the nature of language impairment in Spanish-English bilingual persons with aphasia? It was hypothesized that (1) there would be a relationship between proficiency and lexical semantic performance and that pre-stroke exposure, use, and age of acquisition would be key factors in determining a person's pre-stroke proficiency based on the language use questionnaire, and (2) two distinct profiles of impairment would emerge- parallel impairment (i.e. if Spanish is dominant, Spanish remains dominant post stroke) or differential impairment (i.e. if Spanish was dominant pre-stroke, English is dominant post stroke).

Research Question 1

The results of the study found that factors that make up pre-stroke proficiency differ for L1 and L2. The PCA demonstrated that Daily Usage, Education, Exposure, and Language Ability Rating were key factors in contributing to pre-stroke proficiency in L1. However, based on L2 LUQ scores, AOA, Daily Usage, Family Proficiency, Education, Exposure, Confidence and Language Ability Rating all contributed to a person's pre-stroke proficiency in L2. These results confirm that many factors, what language a person was educated in, their lifetime exposure to each language, their own perception of their abilities, contribute to their overall proficiency in a language (Kroll & Stewart, 1994; Silverberg & Samuels, 2004). One language factor (i.e. AOA or Exposure alone) does not fully capture a person's proficiency, particularly for L2. This raises the concern that studies that describe only one aspect of a bilingual's language profile such as age of acquisition (Tschirren et al., 2011) may be missing important information about the overall profile. These findings have implications for assessment of bilingual individuals with aphasia. In line with Munoz and Marquardt's (2002) assertion, this study confirms that a comprehensive measure of pre-stroke language abilities is essential to understanding a person's pre-stroke proficiency and the subsequent loss of language post-stroke.

Furthermore, the regression analyses confirm that pre-stroke language proficiency is a key determiner of performance on standardized language assessments post-stroke, such that the higher proficiency pre-stroke, the higher performance on standardized tests post-stroke. This pattern was more clear when English was L1 or L2 relative to when Spanish was L1 or L2 as demonstrated by the significant interaction on the regression analysis between language of L1 and proficiency. This may be due, in part, to the fact that all participants were bilingual Spanish-English speakers presently living in the United States. While the participants had varying amounts of time spent in the United States, all were living in the United States at the time of their completion of the LUQ and standardized language assessments. It is possible that the LUQ may not adequately capture or underestimate Spanish proficiency for Spanish-English speakers living in the United States. This observation is consistent with the results of Kiran and Gray (2013) in which they found similar discrepancies between the strength of correlations between English and Spanish standardized language measures. They hypothesized this may be due in part to the study taking place in an English dominant country, that the Spanish BAT and BNT metrics do not substantially assess the Spanish language, or that the patient group was more accustomed to testing in English (Kiran & Gray, 2013). This may be true of our results as well and may explain why English proficiency is a stronger predictor of English language assessment scores.

Nevertheless, our findings have important implications for assessment and diagnosis of aphasia in bilingual individuals particularly when clinicians need to select the language of assessment. Previous studies have not considered impairment as it relates to pre-stroke language abilities (Ansaldo, Saidi, & Ruiz, 2010; Fabbro, 2001; Fabbro, 1999). Others have considered impairment as it relates to specific language factors such as age of acquisition (Tschirren, et al., 2011). Our results demonstrate that a variety of factors contribute to an individual's proficiency in a language and this proficiency does indeed predict post-stroke lexical semantic performance. As such, a person may appear more or less impaired depending upon which language is selected for testing, reinforcing the importance of conducting testing in both languages for bilingual PWA particularly when proficiency differs between languages.

Research Question 2

The second aim of the study was to determine patterns of impairment in bilingual PWA. Two distinct groups emerged. Eighty eight percent (22/25) of participants demonstrated parallel impairment, in that these participants displayed the same trend in each language both pre- and post-stroke (i.e., if Spanish was dominant pre-stroke, it remained dominant post-stroke). Twelve percent (3/25) of participants demonstrated differential impairment in that the language that was dominant pre-stroke was the weaker language post-stroke (i.e. if Spanish was dominant pre-stroke, English was dominant post-stroke). In two of these participants (i.e., P20, P26), their "lower proficiency" language pre-stroke was L2 English, and yet they performed better on standardized language assessments in English than in Spanish post-stroke. It is possible that they underestimated their own proficiency in English on the language use questionnaire as it is their second language, or have acquired more English than they realized by living in an English dominant country. The remaining participant (i.e., P25) that demonstrates differential impairment displays a different profile. This participant's L2 was their higher proficiency language pre-stroke, and yet their performed better post-stroke in L1. Again, it is possible that they underestimated their English proficiency and the influence living in an English dominant country has had on their proficiency.

Overall, these findings of parallel impairment and differential impairment are consistent with Gray & Kiran's (2013) findings of two distinct groups of impairment, parallel and differential, in Spanish-English bilingual PWA. The results are also consistent with Paradis's model of parallel recovery (Fabbro, 1999; Paradis, 2001) and differential recovery in bilingual PWA (Paradis, 2001).

Understanding patterns of impairment in bilingual PWA directly impacts assessment and treatment of bilingual PWA and underscores the need for a comprehensive language questionnaire to assess pre-stroke proficiency. Previous studies have looked at impairment and recovery in bilingual aphasia, but often have not considered pre-stroke language abilities, or when they have, have only considered one aspect of proficiency, such as age of acquisition, (Tschirren et al., 2011). Others have been case studies and as such the results could not be compared across patients (Aglioti & Fabbro, 1993; Fabbro, 1999; Adrover-Roig et al., 2011). This study has expanded upon previous research by incorporating a larger sample size *(n*=27) and utilizing comprehensive proficiency information to understand pre-stroke language abilities as it relates to post-stroke language impairment and document patterns of impairment. The results confirm Gray and Kiran's (2013) findings that different post-stroke diagnostic scores in each language is not necessarily indicative of a differential impairment. Therefore, an understanding of patients' pre-stroke language abilities is crucial in determining the relative loss of each language post-stroke and the profile of impairment, and monitoring progress in therapy.

Limitations and Future Directions

One limitation of this study was the loss of participants. Several participants had to be dropped from the study due to incomplete language use questionnaires or standardized language assessments in one or both languages, reducing the sample size from 47 to 27 individuals. Two participants needed to be dropped from the regression analysis due to missing data. However, as compared to previous research examining bilingual aphasia, the sample size of our study is significantly larger that past studies.

Another limitation of this study is the limited number of L1 English speakers. Twenty-three participants indicated Spanish was their L1, whereas only four participants' L1 was English. Future studies should aim to include equal amounts of L1 English and Spanish speakers when examining proficiency as it relates to post-stroke performance on standardized language assessments. Given that all participants were Spanish-English bilinguals living in the United States, future studies should also examine pre-stroke proficiency in relation to post-stroke performance in bilingual Spanish-English speakers living in Spanish speaking countries.

Overall, our findings suggest that future research should continue to examine and develop measures that accurately measure and assess Spanish-English bilingual's language abilities pre- and post-stroke.

VII. Conclusions

In summary, the results of this study confirm pre-stroke language proficiency is a key determiner of performance on standardized language assessments post-stroke, such that the higher proficiency pre-stroke, the higher performance on standardized tests post stroke. This pattern was more clear when English was L1 or L2 relative to when Spanish was L1 or L2. The results of the study also identified two distinct patterns of language impairment in bilingual PWA. Participants predominantly demonstrated a parallel decrease in language abilities in comparison to pre-stroke proficiency (88%), few demonstrated differential impairment in comparison to pre-stroke proficiency (12%). These results have important implications for assessment and diagnosis of aphasia in bilingual individuals particularly when clinicians need to select the language of assessment.

Appendix A

Language Use Questionnaire

This questionnaire is related to the amount of English and your other language (specify) _________________ you have been exposed to in your life.

1. **At what age did you acquire your second language**? ____________

2. **6 months prior to your stroke, what percent of the time did you speak English and your other language**? ____% English _____% other language

Directions: For activity, include what you are engaged in (e.g., breakfast, work, etc) during your regular day. For partners, include who was interacting with you in the given activity (e.g., mother, grandfather, siblings, etc.). For language(s), use **O** for Other language, **E** for English, **B** for both.

Home Language Profile/Routine: **WEEKDAY**

Time	Activity	Conversation Partner(s)	Language(s)	
7am			Participant	Other English Both
			Partner	Other English Both
8am			Participant	Other English Both
			Partner	Other English Both
9am			Participant	Other English Both
			Partner	Other English Both
10am			Participant	Other English Both
			Partner	Other English Both
11am			Participant	Other English Both
			Partner	Other English Both
12pm			Participant	Other English Both
			Partner	Other English Both
1pm			Participant	Other English Both
			Partner	Other English Both
2pm			Participant	Other English Both
			Partner	Other English Both
3pm			Participant	Other English Both
			Partner	Other English Both
4pm			Participant	Other English Both
			Partner	Other English Both
5pm			Participant	Other English Both
			Partner	Other English Both
6pm			Participant	Other English Both
			Partner	Other English Both
7pm			Participant	Other English Both
			Partner	Other English Both
8pm			Participant	Other English Both
			Partner	Other English Both
9pm			Participant	Other English Both
			Partner	Other English Both
10pm			Participant	Other English Both
			Partner	Other English Both
11pm			Participant	Other English Both
			Partner	Other English Both

<u>Directions:</u> For activity, include what you are engaged in (e.g., breakfast, work, etc) during your regular day. For partners, include who was interacting with you in the given activity (e.g., mother, grandfather, siblings, etc.). For language(s), use **O** for Other language, **E** for English, **B** for both.

Home Language Profile/Routine: ***Weekend***

Time	Activity	Conversation Partner(s)	Language(s)	
7am			Participant	Other English Both
			Partner	Other English Both
8am			Participant	Other English Both
			Partner	Other English Both
9am			Participant	Other English Both
			Partner	Other English Both
10am			Participant	Other English Both
			Partner	Other English Both
11am			Participant	Other English Both
			Partner	Other English Both
12pm			Participant	Other English Both
			Partner	Other English Both
1pm			Participant	Other English Both
			Partner	Other English Both
2pm			Participant	Other English Both
			Partner	Other English Both
3pm			Participant	Other English Both
			Partner	Other English Both
4pm			Participant	Other English Both
			Partner	Other English Both
5pm			Participant	Other English Both
			Partner	Other English Both
6pm			Participant	Other English Both
			Partner	Other English Both
7pm			Participant	Other English Both
			Partner	Other English Both
8pm			Participant	Other English Both
			Partner	Other English Both
9pm			Participant	Other English Both
			Partner	Other English Both
10pm			Participant	Other English Both
			Partner	Other English Both
11pm			Participant	Other English Both
			Partner	Other English Both

Directions: Write the age intervals (in years) of when your parents have lived in the countries stated below. If they have lived all their life in one country please indicate which country.

	Father	**Mother**
United States		
Other country (specify the country)_________________		
All their life in (specify the country)_________________		
Not applicable		

Please rate the ability of the following people in each language. Specify the other language______________________________.

		Proficiency rating				
		Not confident	**25% confident**	**50% confident**	**75% confident**	**Strong confident**
	Language					
Mother	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
Father	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
Siblings	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐

II. Educational History:

How many years of education have you had? ____________________

What was the language you used at school during:	**Other**	**English**	**Both**
Elementary?	1	2	3
High school?	1	2	3
College?	1	2	3
Which language did you prefer to speak at school during:			
Elementary?	1	2	3
High school?	1	2	3
College?	1	2	3
What language did other students speak at school during:			
Elementary?	1	2	3
High school?	1	2	3
College?	1	2	3

Were you taught in any additional languages? YES NO

If so, which language(s)?

Have your language use patterns changed in the last five years? If yes, How?

Directions: From the following age ranges please select which language you heard, spoke and read the most. For example, if you indicate you heard English 75% of the times between the age range 6-9, it means that you heard the other language the remaining 25% of the time. If you were exposed only to one language in a specific age range, please select the 100% box for that language.

	LANGUAGE YOU **HEARD** THE MOST				
	Other language 100%	25%English-75 other%	50%-50%	75% English-25% other	English 100%
Age					
0-3	☐	☐	☐	☐	☐
3-6	☐	☐	☐	☐	☐
6-9	☐	☐	☐	☐	☐
9-12	☐	☐	☐	☐	☐
12-15	☐	☐	☐	☐	☐
15-18	☐	☐	☐	☐	☐
18-21	☐	☐	☐	☐	☐
21-24	☐	☐	☐	☐	☐
24-27	☐	☐	☐	☐	☐
27-30	☐	☐	☐	☐	☐
30 and up	☐	☐	☐	☐	☐

	LANGUAGE YOU **SPOKE** THE MOST				
	Other language 100%	25%English-75 other%	50%-50%	75% English-25% other	English 100%
Age					
3-6	☐	☐	☐	☐	☐
6-9	☐	☐	☐	☐	☐
9-12	☐	☐	☐	☐	☐
12-15	☐	☐	☐	☐	☐
15-18	☐	☐	☐	☐	☐
18-21	☐	☐	☐	☐	☐
21-24	☐	☐	☐	☐	☐
24-27	☐	☐	☐	☐	☐
27-30	☐	☐	☐	☐	☐
30 and up	☐	☐	☐	☐	☐

	L A N G U A G E Y O U **R E A D** T H E M O S T				
	Other language 100%	**25%English- 75 other%**	**50%-50%**	**75% English- 25% other**	**English 100%**
Age					
3-6	☐	☐	☐	☐	☐
6-9	☐	☐	☐	☐	☐
9-12	☐	☐	☐	☐	☐
12-15	☐	☐	☐	☐	☐
15-18	☐	☐	☐	☐	☐
18-21	☐	☐	☐	☐	☐
21-24	☐	☐	☐	☐	☐
24-27	☐	☐	☐	☐	☐
27-30	☐	☐	☐	☐	☐
30 and up	☐	☐	☐	☐	☐

Directions: From the following age ranges please indicate which language gave you the most confidence when speaking, hearing and reading it. Confidence does not mean the language you used the most. It means the language that gave you the most self-confidence when speaking, listening or reading. For example, it might be possible that between 9-12 years of age you heard English at school and your other language at home. However, you felt more self-confident when hearing your other language than English. If you were exposed to only one language in a specific age, answer for the exposed language only.

		C O N F I D E N C E I N **H E A R I N G**				
		Not confident	**25% confident**	**50% confident**	**75% confident**	**Strong confident**
Age	**Language**					
3-6	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
6-9	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
9-12	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
12-15	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐

15-18	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
18-21	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
21-24	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
24-27	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
27-30	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
30 and up	**English**	☐	☐	☐	☐	☐

C O N F I D E N C E I N S P E A K I N G

Age	**Language**	**Not confident**	**25% confident**	**50% confident**	**75% confident**	**Strong confident**
3-6	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
6-9	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
9-12	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
12-15	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
15-18	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
18-21	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
21-24	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
24-27	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
27-30	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
30 and up	**English**	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐

		CONFIDENCE IN READING				
		Not confident	25% confident	50% confident	75% confident	Strong confident
Age	Language					
6-9	English	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
9-12	English	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
12-15	English	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
15-18	English	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
18-21	English	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
21-24	English	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
24-27	English	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
27-30	English	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐
30 and up	English	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐

BEFORE STROKE: Language Ability Rating

We would like to understand how comfortable you are in English and your other language. Please circle the number that best represents your ability to communicate in each speaking and listening situation. Numbers range from **1-5.**

Please see the number descriptions below:

1. I am non-fluent and speak at the single word level.
2. I use phrases to communicate. I understand short sentences. I understand and can use common expressions, greetings, and simple requests.
3. I can participate in simple one-on-one conversation. I communicate primarily using concrete sentences. I do not use elaborate tense changes of grammar when speaking. I can read directions, fill out forms, read medications and bus schedules, etc. My comprehension is augmented when competing distractions are not present, e.g. loud background noise.
4. I can participate in complex conversation, e.g. about detailed opinions, information, politics. I incorporate complex tense changes when speaking. I understand detailed descriptions or instructions, talk on the phone with ease, can follow dialogue in a movie, read newspapers and magazines with ease.
5. Native fluency. I speak this language like my first language. I can explain a concept in multiple ways, I have metacognition (you know grammar is correct because it "sounds" right); I have a rapid, automatic speech rate with minimal word retrieval problems. I understand the majority of idioms, slang, and proverbs.

English	Non-fluent				Native Fluency
Overall ability	1	2	3	4	5
Speaking in casual conversations	1	2	3	4	5
Listening in casual conversations	1	2	3	4	5
Speaking in formal situations	1	2	3	4	5
Listening in formal situations	1	2	3	4	5
Reading	1	2	3	4	5
Writing	1	2	3	4	5

Other language	Non-fluent				Native Fluency
Overall ability	1	2	3	4	5
Speaking in casual conversations	1	2	3	4	5
Listening in casual conversations	1	2	3	4	5

	Non-fluent				Native Fluency
Speaking in formal situations	1	2	3	4	5
Listening in formal situations	1	2	3	4	5
Reading	1	2	3	4	5
Writing	1	2	3	4	5

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CURRICULUM VITAE

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