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Article

A Theoretical Account of Lexical and Semantic Naming Deficits in Bilingual Aphasia

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Purpose: The purpose of this study was to examine premorbid language proficiency and lexical and semantic processing deficits in bilingual aphasia and develop a theoretical account of bilingual language processing.

Method: Nineteen Spanish–English patients with bilingual aphasia completed a language use questionnaire (LUQ) and were administered Spanish and English standardized language assessments. The authors analyzed the data to (a) identify patterns of lexical and semantic processing deficits and conceptualize a theoretical framework that accounts for language deficits, (b) determine LUQ measures that predict poststroke language deficits, and (c) evaluate the relationship between predictive LUQ measures and poststroke language deficits in order to identify impairment patterns.

Results: On the basis of the results, the authors obtained significant correlations on several measures between language input and output. They identified prestroke language ability rating as the strongest predictor of poststroke outcomes. On the basis of these data, 2 distinct groups were identified: (a) patients who lost the same amount of language in Spanish and English and (b) patients who lost different amounts of Spanish and English.

Conclusions: These findings suggest that it is possible to identify relationships between language patterns and deficits in patients with bilingual aphasia and that these trends will be instrumental in clinical assessments of this understudied population.

Key Words: bilingual, aphasia, language, processing, impairment

More than half the world's adult population is bilingual (Ardila & Ramos, 2007). However, the majority of aphasia research studies focus on monolingual individuals, and only a limited number of studies expound upon treating, assessing, and evaluating patients with bilingual aphasia (Roberts & Kiran, 2007). One aspect of bilingual aphasia that researchers must define is the language impairment itself. In order to do this, systematic studies that are theoretically motivated and include numerous patients must be conducted. It is imperative that the bilingual aphasia literature continues to grow in order to best serve the bilingual populations of the world.

Because an important component of the evaluation of bilingual aphasia is the identification of language impairment in both languages, a patient's premorbid language proficiency must be addressed. Paradis (2004) has identified possible *impairment* and *recovery* patterns to describe how languages present after neurological injury. Two impairment classifications are based on preinjury language proficiency (e.g., parallel and differential), whereas the other classifications are based solely on the manner of postmorbid language presentation (e.g., antagonistic) and therefore constitute recovery patterns. It is our intention to focus on impairment patterns in bilingual aphasia. Consequently, premorbid proficiency is also discussed, as it is linked to the identification of impairment patterns.

Just as the identification of language impairment patterns is a vital aspect of bilingual language assessments and the design of therapy programs, it is also imperative that a model of bilingual receptive and expressive language be incorporated into the interpretation of diagnostic evaluations and ongoing therapy. Numerous bilingual language models are currently available from the literature. However, as is discussed, there is not one single model that encompasses both input and output levels of language within a bilingual context.

It is widely accepted that two languages in one brain access a common semantic network, yet models differ on how that access is achieved. Both the mixed model of bilingual lexical representation (de Groot, 1992) and the revised

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hierarchical model (RHM; Kroll & Stewart, 1994) propose that lexical connections in first language (L1) and second language (L2) are linked to conceptual memory representations. The mixed model proposes that L1 and L2 connections consist of direct and indirect links based on semantic (e.g., concrete vs. abstract) and word psycholinguistic variables (e.g., frequency and familiarity). This model suggests that a word with high frequency will strengthen its connection from conceptual memory to L1 or L2. This is reflected in translation performance because translating is thought to engage the conceptual memory component. According to the RHM, asymmetrical connections to conceptual memory are defined by the strength of the bidirectional links, which differ as a function of L1 and L2 fluency. Because second-language learners learn L2 by way of L1, it is believed that L2 is learned via lexical representations, whereas L1 is learned via semantic representations.

Kroll, Bobb, Misra, and Guo (2008) discuss the *mental firewall*, the process by which competition between the target and nontarget is resolved. According to Kroll and colleagues, a language cue automatically activates the target language so that the nontarget language is not a candidate for selection, thereby decreasing its possible role of competition. Although language selection models are still under debate, it is suggested that both language-specific and language nonspecific models are subject to a bilingual's proficiency level (Costa & Santesteban, 2004).

Another model concerned with bilingual language production is de Bot's (1992) bilingual processing model, based on Levelt's (1989) model of monolingual language processing. De Bot's (1992) bilingual model consists of one lexicon shared by two languages and three processing components. It begins with the sublexical conceptualizer, one part of which is hypothesized to be language specific, whereas the other is language nonspecific. The preverbal message is formed at the level of this component and includes information about the target language. At the formulator level, grammatical and phonological encoding of the target language takes place (i.e., the speech plan is formed). The plan is then converted into speech at the articulator level.

De Groot's (1992) mixed model, Kroll and Stewart's (1994) RHM, and de Bot's (1992) bilingual processing model explain lexical representation and access via output processes. In our study, in addition to output processes, we are also interested in input processes. Therefore, we now turn to Dijkstra, van Heuven, and Grainger's (1998) bilingual interactive model (BIA) that accounts for bilingual language comprehension. It was developed as an extension of McClelland and Rumelhart's (1981) monolingual interactive activation model.

The BIA model (Dijkstra et al., 1998) operates on the assumption that the lexicon for L1 and L2 is integrated and that a language-nonselective access mechanism is active during language processing. The primary aspect of this model is the combination of excitatory and inhibitory processes that function in unison. The language input network consists of four levels: feature, letter, word, and language node. As activation flows up the network, each level will excite or inhibit the appropriate feature, letter, or word. Additionally, Dijkstra and van Heuven (2002) developed the BIA plus model, which accounts for phonological and semantic lexical representations in order to better explain bilingual word recognition.

The aforementioned models do not combine receptive and expressive language, nor do they examine how information from different modalities is processed. One model that is particularly successful at explaining language deficits in aphasia and incorporates visual and auditory input and output processes into its framework is the Ellis and Young (1988) model of monolingual language processing. This model, though focused on one language, emphasizes the process of how spoken, written, or visual objects are entered into and retrieved from the semantic system. In order to name a picture of a /table/, the item must first be presented to the semantic system via auditory or written modalities or via the visual object recognition system. Once the information arrives at the semantic system, which identifies the representation or meaning of /table/, the phonological output lexicon is activated in order to retrieve the word form that represents /table/. As the letters are retrieved, the phonological output buffer acts as brief temporary storage that holds the letters as the words are formed. After the letters are properly sequenced, the word is then spoken. An inherent strength in this model is its applicability to analyzing receptive and expressive language deficits in monolinguals (Ellis & Young, 1988). The use of this model in the analysis of disordered language processing enables clinicians to identify specific levels and modalities at which language processing breaks down.

In this brief review of various lexicosemantic input and/or output models in which monolingual or bilingual frameworks are used, it is apparent that each of the models demonstrates strengths that attest to their prominent standing over time. Current bilingual models either explain word retrieval as it relates to expressive language or address comprehension processing of two languages, whereas the monolingual model combines both comprehension and expression while accounting for all modalities of language. In relation to this study, none of the models offer a solid foundation from which we can base our findings of the relationship between lexical and semantic processing in bilingual aphasia.

The benefit of language models is that they provide a framework to constructively interpret data. The intention of the present study was not to develop a language model but to conceptualize a framework of bilingual language processing that accounts for language deficits seen in patients with bilingual aphasia. The application of such a framework is an essential step in the process of explaining language-processing impairments in bilingual aphasia. It would aid clinicians in the diagnostic component of patient evaluations, contribute to the development of appropriate therapy techniques, and, important to the corpus of literature, provide researchers with a template to aid in interpreting their findings.

Interestingly, there are few studies that have referenced theoretical frameworks to analyze their data. A group of studies investigated grammatical category deficits in cross-linguistic contexts and incorporated language models into the analysis (Faroqi-Shah & Waked, 2010; Hernàndez et al., 2008; Kambanaros, 2009; Kambanaros, Messinis, & Anyfantis, 2012; Kambanaros & vanSteenbrugg, 2006; Poncelat, Majerus, Raman, Warginaire, & Weekes, 2007). A study by Weekes and Raman (2008) evaluated the effects of language type and status in one patient with deep dysphasia while discussing various models of language processing. Detry, Pillon, and De Partz (2005) used the RHM (Kroll & Stewart, 1994) to identify levels of language-processing breakdowns in a bilingual woman diagnosed with Broca's aphasia. General results showed that L1 was less impaired than L2.

In 2006, Edmonds and Kiran conducted a semantic naming treatment study in which they examined cross-linguistic generalization in three bilingual patients with aphasia (Spanish–English). The authors discussed premorbid proficiencies determined by an extensive LUQ (Muñoz, Marquardt, & Copeland, 1999) that included specific language history questions about education, family/social life, work, reading/writing, and self-ratings. The authors used theoretical models such as the RHM (Kroll & Stewart, 1994) and de Groot's (1992) mixed model as a basis to build their research paradigm. In essence, the backbone of their study is based on a theoretically driven hypothesis: that the semantic system is connected to both L1 and L2 lexicons (de Groot, 1992; Kroll & Stewart, 1994) and that activation flow is target-language nonspecific. Their findings suggest that L1 and L2 connections can be changed as a function of therapy. By using a model to interpret their findings, the researchers implemented a systematic means to identify replicable patterns in bilingual language processing.

Models of language processing offer potential road maps to identify patterns of language presentations. Depending on the treatment study or research task, researchers are able to apply the models to describe the language profiles of their participants. The implementation of this style of data analysis lends itself to the application of theoretical models of language processing in the clinical setting.

In addition to the inherent value of language-processing models on the evaluation of language deficits in aphasia, a thorough language use and history analysis is vital to a proper evaluation and diagnosis in bilingual aphasia. Yet, the majority of studies that investigate language impairment in patients with bilingual aphasia primarily include case studies that are descriptive in nature (Adrover-Roig et al., 2011; Aglioti, Beltramello, Girardi, & Fabbro, 1996; Aglioti & Fabbro, 1993; Fabbro, Peru, & Skrap, 1997). They lack detailed premorbid language histories and do not integrate bilingual language models to frame theoretical underpinnings of why bilinguals with aphasia exhibit varied presentations of language impairment. With such discrepancies reported in data collection, it is not possible for researchers to compare data across studies.

For example, Aglioti and Fabbro (1993) and Aglioti et al. (1996) both reported on the neuropsychological and neurolinguistic presentation of one patient with bilingual aphasia who sustained a subcortical lesion and presented with paradoxical selective recovery. The patient demonstrated severe impairments in the dominant L1 compared with less dominant L2. Although the authors commented that L1 was the patient's dominant language, they do not elaborate on premorbid language skill or language history; therefore, they are unable to compare poststroke language skill with the original prestroke language baseline. In another case study, Fabbro et al. (1997) compared and contrasted the cases of three bilingual patients (English–Italian and Friulian–Italian) who sustained thalamic lesions. The report consists of a discussion of each patient's neuropsychological assessment and language deficits. Although the goals of the article included the evaluation of patterns of language deficits and recovery between languages, only brief descriptive language histories are included in the article, and theories of lexical processing are not discussed. Without a premorbid language history, one can only comment on recovery status (from the point of injury onward), and it is impossible to comment on a patient's language impairment. Understanding the level of impairment is an essential first step in providing successful language therapy. Studies that include this information make important contributions to the literature because they offer insights into how to improve language rehabilitation techniques.

A more recent example of a bilingual aphasia descriptive case study is provided by Adrover-Roig et al. (2011), who reported on a bilingual Basque–Spanish man who exhibited aphasia impairment and executive functioning deficits secondary to a left basal ganglia hematoma. He demonstrated more severe language impairments in Basque (L1) than Spanish (L2). For premorbid language use, the patient rated both L1 and L2 proficiency as "very good." Before the stroke, L2 was reserved for professional exchanges, whereas L1 was used for social interactions and the home environment, and according to the patient and family members, the patient had been more comfortable in L1. The Bilingual Aphasia Test Part A: linguistic and bilingualism background (Paradis, 1989) was administered in order to create a premorbid language profile; yet, this single case study is primarily concerned with identifying the patient's cognitive profile and comparing it with language skills and performance of executive functioning. The authors do not analyze the language profile in relation to theories of bilingual language processing, but rather discuss concerns regarding implicit and explicit memory systems and their reliance on particular subcortical structures or distributed cortical networks. Given the focus of the study, it is difficult for the reader to identify what processes of the language system break down in relation to premorbid proficiency.

The aforementioned articles provide a backdrop to begin to evaluate language-processing deficits in bilingual aphasic populations. There are limitations because they are case studies and do not include standardized pre- and post-morbid language histories that account for specific pre- and postmorbid language patterns. Nor do the case studies address psycholinguistic properties of language processing by which to hypothesize upon theoretical models of language processing. Furthermore, given these shortcomings, the studies do not offer means to compare outcomes across patients.

One drawback of the above single-subject design studies can be addressed with a larger group of participants. A handful of studies do exist that include a substantial pool of participants. For example, Fabbro (2001) conducted a study that assessed the language recovery patterns of 20 Friulian–Italian individuals with aphasia. Results indicated that 13 patients showed parallel recovery, four patients exhibited greater L2 impairment compared with L1, and three patients showed greater L1 impairment compared with L2. More recently, Tschirren et al. (2011) conducted a pilot study designed to investigate the interaction of late age of acquisition (AoA) on L2 syntactic deficits in bilingual patients with aphasia. On the basis of previous research, the authors postulated that individuals with anterior lesions would present with different L2 syntactic deficits than those with posterior lesions. A total of 12 late-bilingual patients with aphasia (six with anterior lesions and six with posterior lesions) were examined. It was implied that all patients were premorbidly L1 dominant. The authors found that as a group, the L1 and L2 aphasia severity scores did not differ; however, four patients with lesions in the prerolandic area did exhibit lower scores in L2 syntactic processing compared with L1 syntactic processing. Because this study focused on levels of impairment, the authors did not expound upon recovery patterns.

Although these two studies include many participants with bilingual aphasia and identify interesting findings of poststroke language trends, the researchers found mixed results, and the strength of their results would have been more robust if detailed language histories were included in the analysis. For the case of bilingualism, the ability to identify poststroke language impairment rests on prestroke language proficiencies. The omission of comprehensive prestroke language histories does not allow for in-depth analysis of postinjury language impairment. The broad aim of the present article was to emphasize the importance of language background in studies of bilingual aphasia and to use prestroke language history as a means to explore the nature of poststroke bilingual processing and impairment.

Few studies have examined the relationship between premorbid language use and postmorbid language performance in-depth. For example, Muñoz and Marquardt (2003) compared language history (e.g., language exposure, language usage, AoA) and language proficiency self-ratings with poststroke picture naming and identification ability in four Spanish–English patients with bilingual aphasia against that of 20 neurologically healthy Spanish–English adults who were gender-, ethnicity-, and age-matched and completed the same experiment diagnostics. For the control group, results showed that more frequent use of the English language is consistent with between-language differences in proficiency and literacy.

For patients, the authors found three patterns in their results. For two patients (ME and JB), differences in naming and identification scores in Spanish and English were correlated with varying degrees of premorbid skill between two languages instead of a differential impairment. For a third patient (RA), based on his language profile (language history, use, and literacy rating), it was predicted that his performance in English would surpass that in Spanish; however, this trend was not observed, and the authors identified a differential impairment. Finally, the fourth patient (LC) presented with a language profile that predicted similar impairments across languages; however, the English picture naming task was less impaired than the Spanish, whereas the opposite trend in results was observed for the picture identification task. For this patient, the authors speculated that higher English picture naming scores may be attributed to strategies learned in years of English therapy that did not transfer to Spanish. Overall, the experiment results strongly suggest that an in-depth, premorbid language history is a vital piece to the evaluation and identification of deficits and language pattern impairments in bilingual aphasics.

Ideally, all language studies involving bilingual patients will include in-depth language use and history questionnaires that detail language patterns across the lifetime. Without preinjury language use patterns, how is a clinician able to assess postinjury levels of language impairment? This type of information is an important element to the dynamic evaluation of a patient's postinjury language presentation. Only after gathering preinjury usage patterns are we able to evaluate a patient's language impairment secondary to neurological insult.

The purpose of this study was to examine the degree of lexical and semantic processing impairment at different levels within language processing and to evaluate the role of premorbid language proficiency and its influence on postmorbid lexical and semantic deficits. Our central hypothesis is that there is a systematic way in which lexical and semantic deficits present in bilingual individuals with aphasia, and these patterns are affected by prestroke proficiency. By evaluating these relationships in 19 patients, we aimed to conceptualize a theoretical account of bilingual language processing. This type of framework can have implications for targeting effective treatments for bilingual patients with aphasia, and we believe it can be applied to different language combinations not addressed in this study. Finally, we aimed to explain individual patient impairment by examining specific premorbid language proficiency measures. Our specific research questions and hypotheses were as follows:

1. What are the patterns of lexical and semantic processing deficits between the two languages in bilingual aphasia? Using the results from 19 patients on a series of standardized assessments (Bilingual Aphasia Test [BAT], Boston Naming Test [BNT], and Pyramids and Palm Trees Test [PPT]—Picture Version), we examined language impairment trends and attempted to incorporate the results into a theoretical framework. Although we do not expect all patients to show the same patterns of deficits, we do expect systematic patterns to emerge between comprehension, expression, and translation.

2. Does premorbid language proficiency in each language influence poststroke lexical semantic deficits in each language, and if so, to what extent? We predict that self-rating of premorbid language use can be used to determine poststroke language presentation.
3. Are there distinct groups into which patients with bilingual aphasia can be categorized? We do not expect all patients to show the same pattern of poststroke language deficits; however, we do expect to be able to identify distinct patterns of prestroke proficiency and poststroke deficits. We predict that these patterns of language impairment will divide our patients into distinct groups. In addition, consistent with monolingual studies of aphasia, we expect to observe language input to be less impaired than output within our patient data.

Method

Participants

A total of 19 Spanish–English patients with bilingual aphasia were recruited from the Austin, TX and Boston, MA areas. The patients included 11 females ranging in age from 33 to 85.6 years ($M = 63.1$, $SD = 17.82$) and eight males ranging in age from 37 to 75.2 years ($M = 54.4$, $SD = 14.26$). Levels of education ranged from elementary school to college level. All patients were speakers of both Spanish and English prior to stroke, exhibited adequate hearing and vision, and demonstrated stable health status (see Table 1). We considered our patients bilingual if they used two languages regularly in daily life (Grosjean, 1992).

Materials

Language proficiency levels. In order to create language profiles that represent premorbid language use patterns across participants as accurately as possible, each patient, aided by a family member, participated in a thorough language history-based interview conducted by a speech-language pathologist. During this interview, patients and family members completed a comprehensive LUQ (Kiran, Peña, Bedore, & Sheng, 2010) designed to assess premorbid language proficiency and language patterns across a lifetime (see the Appendix in online supplementary materials). The questions focused on pre- and poststroke language use patterns in order to glean the following information specific to each language: (a) age of L1 and L2 acquisition; (b) number of years of exposure in each language; (c) confidence of pre- and poststroke L1 and L2 skills; (d) poststroke "current exposure" that included an account of language(s) spoken and heard by patient during his or her daily routine (weekday/weekend); (e) proficiency of first-degree family members; (f) language of education history; and (g) pre- and poststroke language ability for L1 and L2 using a 5-point scale rating including overall ability, speaking in casual conversations, listening in casual conversations, speaking in formal situations, listening in formal situations, and reading and writing, where 1 represents nonfluent skills (e.g., speaking at the single-word level) and 5 represents native or near–native fluency.

Table 1. Demographic data for all participants.

Participant	Gender	MPO	Age at testing	Location
UT01	M	8	53.8	Austin, TX
UT02	F	9	54.1	Austin, TX
UT07	F	6	56.1	Austin, TX
UT09	F	6	87.9	Austin, TX
UT11	F	9	53.1	Austin, TX
UT16	F	16	56.11	Austin, TX
UT17	M	11	53.7	Austin, TX
UT18	F	30	73.8	Austin, TX
UT19	M	50	75	Austin, TX
UT20	F	41	85.6	Austin, TX
UT21	F	10	88	Austin, TX
UT22	M	3.5	41.4	Austin, TX
UT23	F	3.5	41.5	Austin, TX
BU01	M	84	44.7	Boston, MA
BU04	M	173	37	Boston, MA
BU07	F	7.5	65.2	Boston, MA
BU10	M	14	75.2	Boston, MA
BU12	F	5	33.3	Boston, MA
BU13	M	17	54.5	Boston, MA

Note. MPO = months postonset; M = male; F = female.

Language testing in English and Spanish. In order to provide a theoretical account of language deficits in bilingual aphasia, we conceptualized a framework of bilingual language processing with three distinct and separable levels: (a) auditory input lexicon (comprehension); (b) the semantic system (linguistic and nonlinguistic); and (c) speech output lexicon (verbal expression). We also designated a portion of the model to characterize translation between languages. In order to capture these levels within the framework, patients were administered the PPT–Picture Version (Howard & Patterson, 1992), the BNT (Kaplan, Goodglass, & Weintraub, 1983) in both Spanish and English, the BAT (Paradis, 1989) in both Spanish and English, and the BAT Part C Spanish–English (Paradis, 1989). Spanish and English assessments were conducted on different days, and testing instructions were given in the language that was to be tested that day. For the nonlinguistic PPT, instructions were given in the patient's most comfortable language, which was determined by the language the patient would speak spontaneously. If a patient fatigued during the assessment session, the clinician chose an appropriate time point to take a break. All patients completed testing in a timely manner; however, the number of testing sessions was unique to each patient given that the testing proceeded at the pace of each patient.

Data Analysis

Organization of Data Variables

In order to put all tests onto one framework, we operationally organized the data. For example, the PPT-Picture Version represents pure, nonlinguistic semantic processing at the conceptual level. In a field of two, patients must identify a picture that goes with the target picture. This score was converted into an average (number correct/52) used to establish impairment at the level of nonlinguistic semantics in our framework and is referred to as *Semantics Non-linguistic*. To construct a linguistic semantic system representation, referred to as *Semantics English and Semantics Spanish,* we averaged the following BAT subtests in their respective languages: Semantic Categories, Synonyms, Antonyms I and II, Semantic Acceptability, and Semantic Opposites. To create a quantifiable measure of comprehension for the framework, we created an average score for each language that we refer to as *Comprehension English and Comprehension Spanish*. For this representation of comprehension, we averaged BAT subtests in their respective languages: Pointing, Semi-Complex Commands, and Complex Commands. Finally, each participant has two BNT scores (English and Spanish) (number correct/60) that determine impairment at the speech-output level (single-word naming) in each language. Within the framework, this output representation is labeled as *Expression English* and *Expression Spanish*.

Our framework of language processing in bilingual aphasia contains two more essential features that represent the translation aspect of moving from one language into the other: Word Recognition (receptive language) and Translation (expressive language). Taken from the BAT Part C, the Word Recognition subtest requires patients to look at a list of Spanish words and identify the translation from a list of English words. The patient is also required to perform the reverse word identification, matching words from English into Spanish. In the framework, this task is labeled *Word Recognition Spanish into English* and *Word Recognition English into Spanish*. The final component in our framework of language processing in bilingual aphasia is labeled *Translation Spanish into English* and *Translation English into Spanish*. This output level of the framework is composed of the average of two BAT Part C subtests: Translation of Words and Translation of Sentences. For each direction of translation, we averaged the appropriate directional translation scores from each of the respective translation subtests (see Table 2 for all test results).

Results

Question 1: What Are the Patterns of Lexical And Semantic Processing Deficits Between the Two Languages in Bilingual Aphasia?

All 19 patients were included in this Pearson pairwise correlation. By conducting this type of analysis, we identified significant connections between diagnostic scores that represent specific levels of our framework of language processing in bilingual aphasia. See Table 3 for a list of the diagnostic tests and subtests that represent levels of language processing within the framework. Results revealed that specific components of the framework do significantly correlate with each other (all $ps < .05$). See Figure 1 for an integration of correlation results onto the framework. Semantics Non-linguistic was associated with both Word Recognition results (Semantics Non-linguistic to Word Recognition English

Table 2. Spanish and English diagnostic scores for all participants.

PT	PPT	BNT-E	BNT-S	BAT-Comp E	BAT-Comp S	BAT-Sem E	BAT-Sem S	BAT-Word Rec, E into S	BAT-Word Rec, S into E	BAT-Tran, E to S	BAT-Tran, S to E
UT01	DNT	0	0	38	15	28	40	20	40	0	5
UT02	90	43	40	78	75	73	73	100	100	30	31.5
UT07	DNT	23	18	80	88	53	62	100	100	5	10
UT09	DNT	57	10	97	75	67	42	DNT	DNT	DNT	DNT
UT11	75	8	5	52	45	23	15	100	100	5	33.5
UT16	DNT	5	5	63	60	75	48	100	100	67	89
UT17	87	52	8	82	93	52	58	60	100	43	61
UT18	77	28	32	67	83	62	77	100	80	95	61
UT19	75	3	47	17	75	DNT	32	40	60	8	11
UT20	71	0	0	DNT	27	DNT	20	20	60	0	0
UT21	48	2	0	17	20	DNT	DNT	0	0	0	0
UT22	83	5	47	57	90	40	72	60	80	8	13
UT23	90	0	2	63	70	40	55	100	100	0	0
BU01	92	37	43	70	80	53	55	60	80	49	60
BU04	94	58	12	70	62	60	48	80	100	0	36
BU07	52	0	15	7	67	23	38	DNT	DNT	DNT	DNT
BU10	73	3	42	40	73	30	50	60	60	3	13
BU12	100	0	0	42	55	42	53	80	100	0	0
BU13	88	0	0	68	75	23	33	60	20	0	0
M (*SD*)	80 (14.3)	17 (21.0)	17 (17.6)	56 (24.1)	65 (22.4)	47 (17.3)	48 (16.6)	67 (31.3)	75 (30.3)	18 (27.7)	25 (26.9)

Note. PT = Patient; PPT = Pyramids and Palm Tree (Howard & Patterson, 1992); BNT = Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983); E = English; S = Spanish; BAT = Bilingual Aphasia Test (Paradis, 1989); Comp = Comprehension; Sem = Semantics; Rec = Recognition; Trans = Translation; BAT Comp E and BAT Comp S are averages from subtests: Pointing, Semi-Complex Commands, and Complex Commands; BAT-Sem E and BAT-Sem S are averages from subtests: Semantic Categories, Synonyms, Antonyms I and II, Semantic Acceptability, and Semantic Opposites; BAT-Trans S into E and BAT-Trans E into S are averages from subtests: Translation of Words and Translation of Sentences; DNT = Did not test.

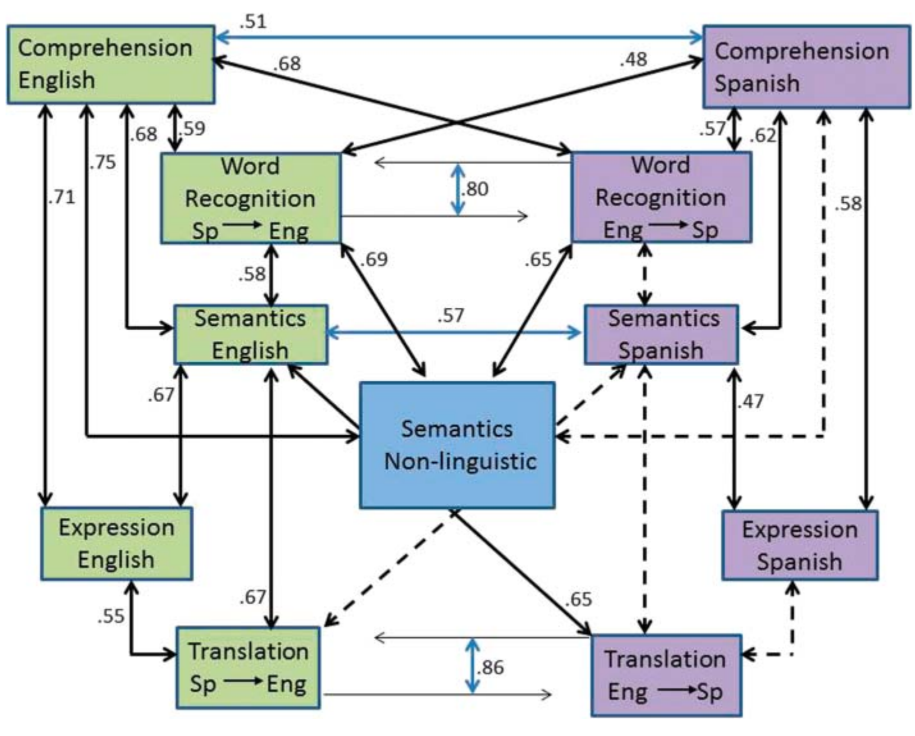
Table 3. List of diagnostic tests or subtests (averages) that represent specific levels within the framework of bilingual language processing.

Framework level	Test/subtests
Semantics nonlinguistic	PPT Picture Version
Semantics English Semantics Spanish	BAT: Semantic Categories, Synonyms, Antonyms I and II, Semantic Acceptability, and Semantic Opposites
Comprehension English Comprehension Spanish	BAT: Pointing, Semi-Complex Commands, and Complex Commands
Expression English Expression Spanish	BNT
Word Recognition Spanish into English Word Recognition English into Spanish	BAT Part C: Word Recognition
Translation Spanish into English Translation English into Spanish	BAT Part C: Translation of Words and Translation of Sentences

into Spanish, *r* = .65; Semantics Non-linguistic to Word Recognition Spanish into English, *r* = .69). In their respective languages, Comprehension correlated with Semantics Linguistics, Expressive output, and bidirectional Word Recognition (Comprehension English to Semantics English, *r* = .68, Comprehension English to Expressive English, *r* = .71, Comprehension English to Word Recognition Spanish into English, *r* = .59, and Word Recognition English into Spanish, *r* = .68; Comprehension Spanish to Semantics Spanish, *r* = .62, Comprehension Spanish to Expressive Spanish, *r* = .58, and Comprehension Spanish to Word Recognition English into Spanish, *r* = .57, and Word Recognition Spanish into English, *r* = .48). Both Semantics Linguistic scores are associated with Expression scores in their respective languages (Semantics English to Expression English, *r* = .67; Semantics Spanish to Expression Spanish, *r* = .47).

Significant correlations among complementary counterparts within the model were also identified. Comprehension English was associated with Comprehension Spanish (*r* = .51); Word Recognition Spanish into English and its reciprocal representation were correlated (*r* = .80); Semantics

Figure 1. Framework of bilingual language processing. All levels of input and output are labeled and arranged in their respective positions. The right side of the model represents English, and the left side represents Spanish. As to be expected, the Semantics Non-linguistics is in the center. Just above that are the Semantics Linguistic representations: Semantics English on the left and Semantics Spanish on the right. The upper-most left and right corners of the diagram display Comprehension English and Comprehension Spanish, and finally the lower left and right corners show Expression English and Expression Spanish. Word Recognition represents the ability to identify words across languages at the input level and is placed in the model just below Comprehension. Word Recognition Spanish into English is on the left side of the model, whereas Word Recognition English into Spanish is on the right. Finally, Translation English into Spanish and Translation Spanish into English are classified as output components and are placed on their respective sides of the model. Significant associations are represented by solid lines and Pearson coefficients, whereas dotted lines represent theoretical assertions. All *p*s < .05.



English and Spanish were found to be associated (r = .57); and finally, Translation Spanish into English and the reverse were associated (r = .86). Asymmetrical correlations were also observed. Comprehension English was associated with Semantics Non-linguistics (r = .75), and Semantics English was associated with Word Recognition Spanish into English (r = .58), Translation Spanish into English (r = .67), and Translation English into Spanish (r = .65). See Table 4 for all correlation results.

Question 2: Does Premorbid Language Proficiency in Each Language Influence Poststroke Lexical Semantic Deficits in Each Language, and If So, To What Extent?

Using the LUQ, we collected information pertaining to each patient's language history for both Spanish and English. All patients were native Spanish speakers who learned English at varying ages; some were early learners (e.g., < 6 years old), and some were late learners (e.g., > 6 years old). Patients UT02, UT07, UT09, and UT11 were omitted from the analysis because they completed less than half of the LUQ. Two patients were missing two data cells from the LUQ, which was addressed in the statistical tests through a casewise elimination procedure (see Table 5 for LUQ profiles). Specifically, data reflected lifetime exposure, poststroke current exposure, prestroke language ability rating (LAR), confidence, family proficiency, and education history. Given that we had six language variables, our goal was to reduce the number of variables entered into our analysis.

First, we conducted a Pearson correlation to evaluate the relatedness of each potential predictor. The results revealed that all language variables were highly related. Following this, we ran a principal-components analysis (PCA) controlling for language in order to examine the relationship between the variables. The PCA showed that the first factor with an eigenvalue of 4.68 accounted for 78% of the variance. However, within this factor, all loaded variables were highly correlated with each other. Because there were no specific factors that stood out in this analysis, we did not reduce the data into subclusters. See Table 6 for PCA results.

Then we performed two multiple regressions to identify possible effects of multicollinearity among the language predictors, identifying variance inflation factors (VIFs) > 10. Controlling for language, first we regressed BNT scores against all six language predictors, and then we regressed BAT Comprehension scores against the same language predictors. None of the regression equations were significant. For BNT and BAT Comprehension English, we found that language exposure (VIF = 17.26), family proficiency (VIF = 12.03), and education history (VIF = 11.54) demonstrated a high level of multicollinearity, whereas poststroke current exposure (VIF = 7.41), confidence (VIF = 7.29), and prestroke LAR (VIF = 8.10) did not. For BNT and BAT Comprehension Spanish, we found that all language predictors did not demonstrate multicollinearity; however, we did identify higher VIFs for language exposure, education history, and current exposure. From these results, we chose to include confidence, prestroke LAR, and poststroke current exposure as the language predictors in the regression model designed to identify language variables that predict poststroke lexical and semantic deficits.

We conducted four multiple regressions to examine the relationship between the language predictors (confidence, prestroke LAR, and poststroke current exposure) and BAT Comprehension, BAT Semantics, BNT, and BAT Word Recognition. Language (Spanish, English) was included as the categorical variable. We did not include BAT Translation in any regressions due to the number of empty data points. Of the four regressions, two equations were significant, specifically BAT Comprehension (R^2 = .499), $F(3, 22) = 7.33$, $p \leq .01$, and BAT Semantics (R^2 = .33), $F(3, 21) = 3.57$, $p \leq .05$, and BNT was trending on significance (R^2 = .25), $F(3, 22) = 2.52$, $p = .08$. Of the two significant equations, prestroke LAR was the only significant predictor, for BAT Comprehension ($\beta = 0.55$, $t = 2.33$, $p = .02$)

Table 4. Correlation matrix results.

Variable	1	2	3	4	5	6	7	8	9	10	11
1. BNT Eng	—										
2. BNT Sp	.19	—									
3. PAPT	.43	.08	—								
4. BAT Comp Eng	**.71**	−.01	**.75**	—							
5. BAT Comp Sp	.44	**.58**	.47	**.51**	—						
6. BAT Semantics Eng	**.67**	.22	.49	**.68**	.34	—					
7. BAT Semantics Sp	.37	**.47**	.38	.40	**.62**	**.57**	—				
8. BAT Word Rec. Eng into Sp	.33	.13	**.65**	**.68**	**.57**	.50	.43	—			
9. BAT Word Rec. Sp into Eng	.47	.15	**.69**	**.59**	**.48**	**.58**	.39	**.80**	—		
10. BAT Trans Eng into Sp	.40	.28	.09	.40	.39	**.65**	.49	.39	.30	—	
11. BAT Trans Sp into Eng	**.55**	.20	.23	.48	.35	**.67**	.29	.44	.47	**.86**	—

Note. Eng = English; Sp = Spanish; PAPT = Pyramids and Palm Tree; BAT Comp Eng and BAT Comp Sp are averages from subtests: Pointing, Semi-Complex Commands, and Complex Commands; BAT Semantics Eng and BAT Semantics Sp are averages from subtests: Semantic Categories, Synonyms, Antonyms I and II, Semantic Acceptability, Semantic Openness; BAT Word Rec. Sp into Eng and Eng into Sp is the Word Recognition subtest from BAT Part C; BAT Trans Sp into Eng and BAT Trans Eng into Sp are averages from BAT Part C subtests: Translation of Words and Translation of Sentences. Boldface type represents values significant at $p < .05$.

Table 5. Language history and language ratings across languages for all participants.

Patients	AoA, E	AoA, S	LE, E	LE, S	Conf, E	Conf, S	Poststroke CE, E	Poststroke CE, S	Pre-stroke LAR, E	Pre-stroke LAR, S	Ed Hx, E	Ed Hx, S	Fam Prof, E	Fam Prof, S
UT01	0	0	75	25	100	83	94	6	100	40	100	0	83	83
UT02	21	0	31	69	DNT	DNT	DNT	DNT	90	100	DNT	DNT	DNT	DNT
UT07	0	0	DNT	DNT	DNT	DNT	DNT	DNT	94	31	100	0	DNT	DNT
UT09	5	0	DNT	DNT	DNT	DNT	DNT	DNT	100	82	100	0	DNT	DNT
UT11	11	0	DNT	DNT	DNT	DNT	DNT	DNT	98	100	DNT	DNT	DNT	DNT
UT16	0	0	62	38	99	94	62	38	94	74	67	33	100	100
UT17	6	0	66	34	96	98	55	45	100	100	58	42	75	100
UT18	17	0	40	60	80	100	0	100	100	100	25	75	58	100
UT19	27	0	16	84	13	76	15	85	20	100	0	100	0	100
UT20	69	0	5	95	2	100	12	88	DNT	DNT	0	0	0	100
UT21	5	0	72	28	100	100	99	1	DNT	DNT	100	0	100	100
UT22	18	0	10	90	11	92	38	63	34	94	0	100	17	100
UT23	9	0	33	67	42	100	29	71	66	94	22	78	33	100
BU01	19	0	28	72	42	94	22	78	89	89	0	100	33	100
BU04	7.5	0	74	26	81	100	66	34	100	49	100	0	67	100
BU07	45	0	10	90	5	100	2	98	32	100	0	100	0	100
BU10	40	0	4	96	15	100	0	100	47	100	0	100	0	100
BU12	12	0	28	72	54	100	46	54	80	100	28	72	65	100
BU13	4	0	16	84	100	100	3	97	34	100	58	42	8	100

Note. AoA = age of acquisition in years; LE = lifetime exposure; Conf = confidence; CE = current exposure; LAR = language ability rating; Ed = education; Hx = history; Fam = family; Prof = proficiency.

and BAT Semantics (β = 0.65, t = 2.43, p = .023). In order to address lesion site, level of education, months post onset (MPO), and age at testing, we also regressed these variables against the aforementioned standardized test scores. Nothing of interest was found to be significant.

Question 3: Are There Distinct Groups Into Which Patients With Bilingual Aphasia Can Be Categorized?

On the basis of the regression equations, prestroke LAR was the only significant predictor; therefore, we used this measure to represent prestroke language use. We chose to use BAT Comprehension (average of subtests Pointing, Semi-Complex, and Complex Commands) and BNT scores to represent poststroke comprehension and single-word naming deficits in English and Spanish. We then compared individual prestroke LARs with language deficits. By performing this analysis of visual inspection, we established two groups of poststroke language impairment presentations among our patients. On the basis of available test scores for each patient, 17 patients were included in this analysis.

Group 1a (n = 6) and 1b (n = 4) consisted of patients who demonstrate parallel language impairment. The difference arose in prestroke LAR distributions. In Group 1a, the patients reported *different* levels of prestroke LARs (more than 20%). For example, UT09 exhibited a higher prestroke LAR in English compared with Spanish, and the languages maintain this pattern of unequal skill level in the poststroke position. The patients in Group 1b reported *similar* levels of prestroke LAR (less than 20%). For example, BU01 and UT11 exhibited similar prestroke LARs in both languages and similar comprehension and expression scores that are lower than their self-report prestroke proficiency. In general, patients in Group 1 lost the same amount of language skill across languages, and the prestroke language proficiency levels were either similar or different (see Figure 2, Group 1a and 1b).

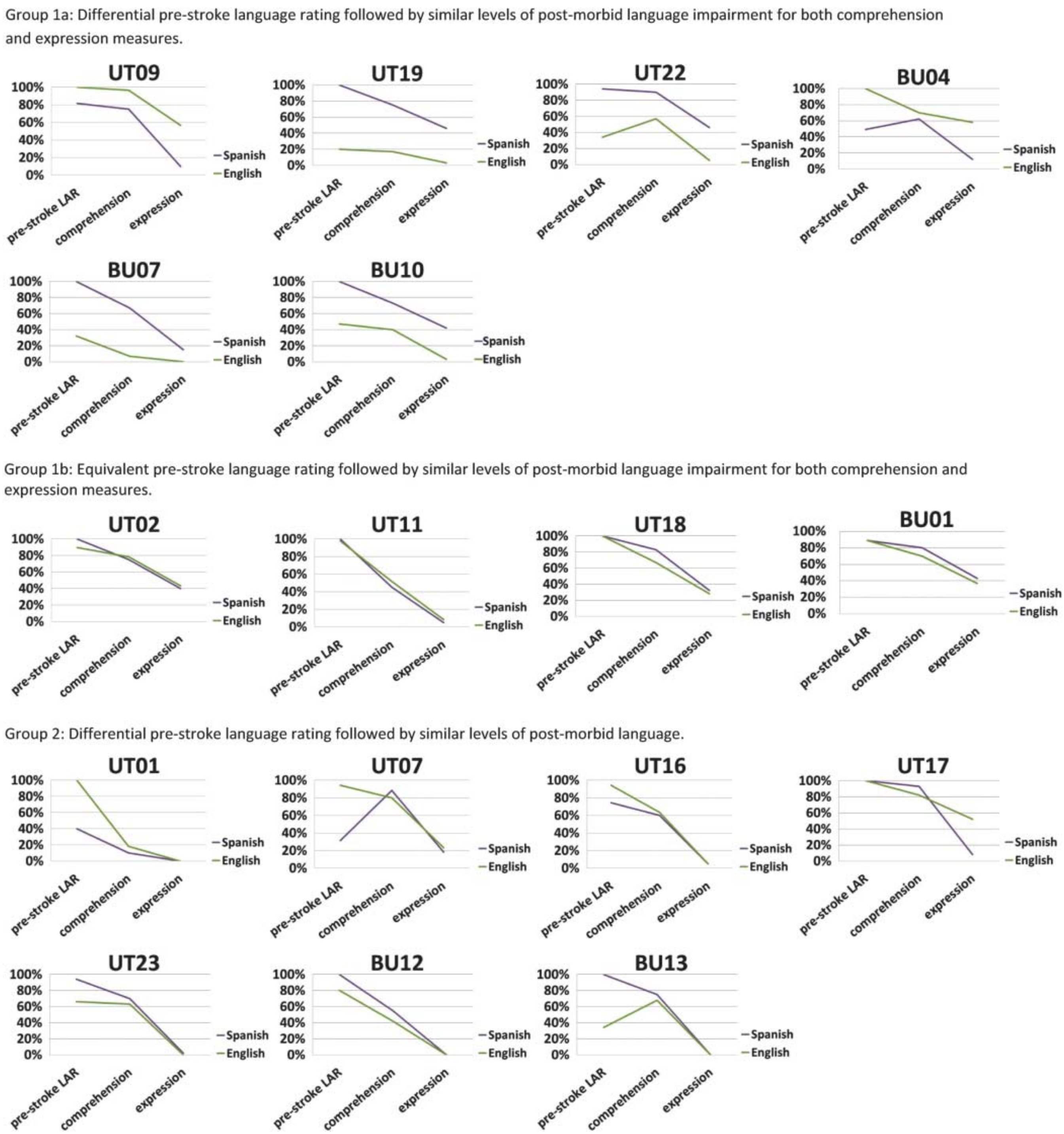
Unlike the first group, patients in Group 2 demonstrated more language loss in one language relative to the other (n = 7). They exhibited differential prestroke LARs (greater than 20% difference) and relatively similar comprehension and expression scores (less than 20% difference). For example, UT01 and UT16 reported different prestroke LARs (English greater than Spanish), yet presented with nearly identical poststroke language deficits. BU12 demonstrated the same outcomes; however, she rated her prestroke LAR Spanish as greater than her prestroke LAR English. UT17 was one exception to the pattern identified in this

Table 6. Factor loadings of the independent variables.

Independent variable	Factor 1	Factor 2	Factor 3	Factor 4
Pre-LAR	0.875438	0.022061	0.413156	0.241883
Postcurrent exp	0.894567	0.290722	0.016747	0.289036
Lifetime exposure	0.951406	0.213896	0.014395	0.023606
Confidence	0.812590	0.506016	0.225960	0.112714
Family proficiency	0.877229	0.365235	0.105605	0.229591
Education history	0.884531	0.281157	0.273639	0.202459
Variance (%)	78.06	9.98	5.13	4.15
Eigenvalue	4.68	0.60	0.31	0.25

Note. Pre-LAR = prestrike language ability rating; postcurrent exp = poststroke current exposure.

Figure 2. Impairment graphs (prestroke LAR = prestroke language ability rating). Group 1a: Differential prestroke language rating followed by similar trending postmorbid language impairment for both comprehension and expression measures. Group 1b: Equivalent prestroke language rating followed by similar levels of postmorbid language impairment for both comprehension and expression measures. Group 2: Differential prestroke language rating followed by similar levels of postmorbid language impairment for both comprehension and expression measures.



group. This patient did demonstrate greater loss in one language relative to the other language, except that he rated prestroke LARs as equal, and his poststroke language scores were unequal (see Figure 2, Group 2).

Discussion

The overarching goal of this study was to provide a theoretical account of lexical and semantic impairments in bilingual aphasia and conceptualize a framework of bilingual language processing based on the following three questions:

1. What are the patterns of lexical and semantic processing deficits between the two languages in bilingual aphasia?
2. Does premorbid language proficiency in each language influence poststroke lexical semantic deficits in each language, and if so, to what extent?
3. Are there distinct groups into which patients with bilingual aphasia can be categorized?

On the basis of previous psycholinguistic models of language processing (de Groot, 1992; Ellis & Young, 1988; Kroll & Stewart, 1994) and by evaluating diagnostic data from 19 Spanish–English patients with bilingual aphasia, we conceptualized a framework of bilingual language processing that integrates specific levels of language processing. Although our framework does not integrate multiple modalities for input and output levels of communication, it does account for verbal comprehension, linguistic and nonlinguistic semantics, verbal translation, and verbal expression. The foundation of the framework is constructed from psycholinguistic models of normal language processing, but correlations from data of patients with bilingual aphasia validate the connections in our framework. It is important to emphasize that (a) these correlations do not explain directionality between levels within the bilingual language framework but rather identify significant connections between language levels, (b) the correlations are representative of our data set, and (c) because the framework is meant to explain a diverse set of test results, we believe other researchers examining bilingual aphasia can use it as a starting point. What follows is the explanation of how our data validates the framework.

Semantics Non-linguistic is associated with Word Recognition Spanish into English and English into Spanish. This suggests that the comprehension of words is a function of basic, core, nonlinguistic knowledge; that is, if a patient can identify the nonlinguistic semantic representation of a word, the patient will be able to identify the translation of that word. Semantics Non-linguistic is also correlated with Comprehension English. Theoretically, this indicates that if Comprehension English is intact, Semantics Non-linguistic will likely be intact. We did not see a significant correlation between Semantics Non-linguistic and Comprehension Spanish, although it is interesting to recognize that the correlation was relatively strong ($r = .47$). The lack of significance could be due to the relatively small number of patients or differences in patient comfort levels in testing in English versus Spanish.

In both languages, Comprehension is correlated with linguistic Semantics and Expression in their respective languages. This suggests that the ability to understand words in English (or Spanish) is indicative of intact linguistic semantics and the ability to say words in that same language. For example, if the ability to understand the word /*book*/ is intact, so is the ability to understand its linguistic meaning and the ability to produce the word verbally. Conversely, if a patient performs poorly on Comprehension in one language, theoretically he or she would also show poor linguistic semantics and expression skills in that same language. Comprehension in both languages is also related to Word Recognition Spanish into English and Word Recognition English into Spanish. This indicates that in order to identify a word's translation, both the prime and target language must be understood.

We would also like to highlight the significant connections between corresponding levels of the framework. Four sets of correlations were significant in a bidirectional fashion: Comprehension, Semantics, Word Recognition, and Translation. These types of significant associations indicate that the ability to perform a specific task in one language (e.g., identify words or translate words across languages) is a skill that is maintained in a bidirectional fashion. However, theoretically, the reverse is also true for poor skill level, meaning that if a patient is unable to translate into English, he or she will not be able to translate into Spanish. Interestingly, there is not a significant correlation between Expression English and Expression Spanish. Perhaps this makes logical sense. The BNT (Spanish and English versions) is the standardized assessment we used to represent Expression in both languages. Because approximately half our patients scored poorly or moderately in both Spanish and English on this test, it is possible that there was not enough variance in the data to accurately represent a significant correlation between the Spanish and English test scores. Another hypothesis is that BNT Spanish is a poor metric of Spanish expression skills (Kohnert, Hernandez, & Bates, 1998; Roberts, Garcia, & Desrochers, 2002). However, we chose to use BNT for the expression portion of our framework because it is a widely used standardized test. We could have added a category-generation component, but that type of task is not coherent with the rest of the network as it requires executive functioning and control that we cannot account for in this framework.

As mentioned, not all of our correlations between levels of language representation in our framework are symmetrical. To represent the asymmetrical correlations within the framework (see Figure 2), nonsignificant dotted lines are on the Spanish side of the framework. On the basis of our data that illustrate associations between levels within the framework, we should see significant associations between Comprehension Spanish and Semantics Non-linguistic and between Expression Spanish and Translation English into Spanish. The fact that we do not see these symmetrical counterparts to the English connections does not mean that the Spanish connections do not exist (see Table 4 for all correlation values). Another observation is that all significant coefficients are stronger on the English side of the model. For example, Comprehension English is correlated with Expression English (r = .71), whereas the r value for the Spanish counterpart is .58. This observation is interesting given that the English side of the framework also contains more significant correlations compared with the Spanish side. We hypothesize that the lack of significant correlations and the discrepancies between strength of correlations on the English side versus the Spanish side of the framework may reflect our heterogeneous patient population, our relatively low number of participants in the study, the fact that the study is taking place in an English-dominant country, or that the Spanish BAT and Spanish BNT metrics do not substantially assess the Spanish language. One more reason is that perhaps our patient group is more accustomed to testing in English. In sum, these are interesting outcomes of the correlation analysis and beg for further research studies to address the variations in the outcomes.

A final observation is that Word Recognition Spanish into English is correlated with Semantics English, which is correlated with Translation Spanish into English. These significant connections indicate that the ability to identify translations in English is indicative of the ability to identify linguistic semantics in English and the ability to translate words into English. The same pattern is not observed with the corresponding Spanish levels in the model. Furthermore, Semantics English is also significantly associated with Translation English into Spanish, whereas the reverse is not significant. From our data set, it appears that the expressive language system places more reliance on Semantics English compared with Semantics Spanish. However, this may reflect our low number of patients, illustrate a remnant of test reliability, or suggest that our patients respond differently to testing in English versus Spanish.

To summarize, the correlations explain the connections between various levels of language represented in the framework. The fact that our data do not confirm all connections as significant gives credence to the connections that are present and validates what these tests actually assess. In turn, it also speaks to our patient population, or the possibility of standardized assessments demonstrating poor metrics. Although there has been much progress in the development of bilingual assessment materials, more work based on theoretical frameworks needs to be done (Roberts & Kiran, 2007). A potential drawback of our framework is that it is based solely on standardized tests, and we acknowledge that language history and language proficiency are contributors to the strengths between connections within the framework and warrant further research. Although our framework is still in its infancy and contains room for improvement, we strongly believe that its base will not change because it is constructed from actual patient data. Ultimately, an unparalleled benefit of conceptualizing a framework of bilingual language processing is to provide clinicians with a tool when assessing bilingual patients with aphasia.

In addition to developing a framework of bilingual language processing, we also intended to identify a metric of premorbid language skill that is predictive of postmorbid lexical and semantic deficits, as identified by standardized language tests. Our findings indicate that prestroke LAR is significantly related to patient poststroke performance in Spanish and English on specific diagnostic tests. To our knowledge, this is the only study to date that has been able to identify a language-use metric as a predictor of poststroke language deficits. By no means are we claiming that prestroke LAR is the best or only measure to use when determining language deficits across languages. Because prestroke LAR is a relatively subjective measure that oftentimes requires the assistance from family members, it is surprising that it is the factor most likely to predict poststroke language impairment. Because this analysis included data from only 15 patients, further research to confirm our findings is desired, and we hope that other predictive factors emerge in future studies. Previous studies have stressed the importance of pre- and postmorbid language-use data when interpreting bilingual aphasic data (Edmonds & Kiran, 2006; Muñoz & Marquardt, 2003), and we would like to emphasize this point that future studies of bilingual aphasia should appreciate the influence of language history information and the fact that it contributes to the dynamic interpretation of study results.

The final goal of this study was to identify groups of patients based on possible LUQ predictors. We used the predictive prestroke LAR as a means to evaluate individual patient performance on bilingual measures of auditory comprehension and verbal expression. We aimed to identify levels of impairment across languages rather than look at recovery patterns. Measures of language recovery are essentially measures of only poststroke data—language presentation at time of stroke compared with language presentation at various time points after stroke. In our analysis, we evaluated a measure of prestroke language proficiency (prestroke LAR) alongside poststroke language deficit data, which enabled a visualization of language impairment.

Two distinct groups of impairment patterns emerged from this analysis. The first group includes patients with parallel language impairment such that they demonstrate relatively equal language loss in both Spanish and English. The difference between Group 1a and 1b is that the first group rates their prestroke LARs as unequal, whereas the second group rates their prestroke LARs as equal. Group 2 consists of patients demonstrating differential language impairment. Specifically, patients in this group demonstrate more language loss in one language compared with the other language. Interesting patterns arise when analyzing individual patient presentations. For example, four patients (UT22, UT07, BU04, and BU13) identify lower prestroke LAR values for their weaker language than what was reported by poststroke comprehension language testing. It could be that these patients were more cautious to rate their weaker language and underestimated its proficiency level. Due to the subjectivity embedded in the prestroke LAR measure, it was assumed that discrepancies of this nature would emerge in the data. In fact, it was surprising that prestroke LAR was the most likely predictor of all LUQ measures. However, past studies have confirmed the validity of measures of self-report (Delgado et al., 1999; Kohnert et al., 1998; Li, Sepanski, & Zhao, 2006).

Most notably, the two distinct patterns of impairment are observed independent of language-type proficiency. For example, Group 1a includes patients who were self-rated as stronger in English as well as others who rated themselves as stronger in Spanish. The same observation is made for Group 2. The core concept we would like to emphasize is that the language presumed to be stronger by the patient is not indicative of an impairment pattern (i.e., how a patient is categorized into a group). Furthermore, this observation strengthens our findings so far as they extend to language combinations other than Spanish and English.

By evaluating language impairments in our patients, we also observed specific trends of language deficits that correspond to monolingual aphasics. In step with patterns of general language deficits from monolingual studies, all of our patients exhibited skill levels of comprehension that were less impaired than those of expression. Another general finding directed our attention toward Paradis' models of language recovery. The results of our study revealed that the stronger premorbid language remained stronger postmorbidly (which we regard as an impairment pattern because it requires premorbid language information), which is complementary to Paradis' model of "parallel recovery" and consistent with previous research (Fabbro, 2001; Paradis, 2004). We also identified patterns of differential impairment that are similar to Paradis' model of "differential recovery" (Paradis, 2004).

Understanding bilingual language impairment patterns allows the clinician to have a better grasp on a patient's language deficits. This discernment between language patterns contributes to the language assessment and directly impacts the language therapy program designed for that individual. In line with Muñoz and Marquardt's (2003) findings, clinicians must understand and incorporate language history data into the analysis of a language assessment because different diagnostic scores between two languages are not necessarily indicative of differential language impairment. In addition, in order to monitor patient progress of language recovery, it is vital that clinicians understand language impairment, which is influenced by premorbid language skill as opposed to postmorbid language skill.

Conclusion

In summary, this study revealed three main results. First, we have conceptualized a framework of bilingual language processing based on psycholinguistic models of normal processing and validated by language deficits from 19 Spanish–English patients with bilingual aphasia. This framework explains connections between receptive and expressive language and translation and has the potential to provide clinicians with a template to map out patient deficits. Our findings also indicate that prestroke LAR is a predictor of poststroke performance on various standardized metrics of language assessments. We then identified two groups of language impairment trends observed from prestroke LAR and specific metrics that evaluated comprehension and expression language in both Spanish and English. Interestingly, these impairment trends were independent of each patient's self-rated, premorbidly dominant language, or L1, which indicates that our findings based on Spanish–English bilingual aphasics can be extended to bilingual populations with other language combinations. Furthermore, our results identify patterns of language impairment across languages within a bilingual brain, which may aid diagnosis and ongoing language treatment.

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