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Language Impairment Differences Between Bilinguals and Monolinguals With Right Hemisphere Brain Injury

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Abstract

The right hemisphere (RH) plays a significant role in language and communication (Brookshire, 2007). However, its contributions are often overshadowed by those of its counterpart, the left hemisphere (LH). An acquired language disorder, or aphasia, occurs when a language area of the brain has been damaged (Darley, 1975). For most all monolinguals, aphasia occurs as a result of injury to the LH (Knecht et al., 2008). However, the organization of bilingual's two languages is thought to not always mirror that of monolinguals. Bilinguals have been shown to have greater RH involvement in the processing of their second language (L2) than in their first language (L1), or than is seen for monolinguals (Ding, 2003). Given that there is greater RH participation for language in bilinguals, this study attempted to see if there were significant differences between the pattern of language deficit profiles in bilinguals compared to monolinguals following RH brain injury. And, subsequently, if injury to the RH caused different degrees of language impairment for bilinguals between their L1 and L2. The results demonstrated that bilinguals had greater language impairments in their L2 following RH injuries. Further, overall bilingual language deficits could not be predicted based on cognitive deficits and/or time since injury to the same degree of accuracy as monolinguals with RH injuries. These findings support the need to view bilinguals with RH brain injuries as distinct from monolinguals in order to best evaluate and treat the differences in etiology and impairment of their two languages.

KEYWORDS: aphasia, bilingual, cerebrovascular accident (CVA), first language (L1), left hemisphere (LH), right hemisphere (RH), second language (L2)

Chapter One: Introduction

Are bilingual brains different than monolingual brains? Is the way a bilingual brain processes and uses language different than that of a monolingual brain? Given the large proportion of the world that speaks more than one language (U.S. Census Bureau, 2011), it is critical to understand how bilingual brains function. Rather than viewing bilingual brains as composites of two monolingual fractions, they instead must be viewed as an integrated whole with distinct abilities and profiles (Grosjean, 1989). This may allow for a greater ability to observe the differences between bilinguals and monolinguals. It is paramount that clinicians fully comprehend potential differences in the organization and structure of bilingual brains in regard to language, in order to be able to effectively assess and treat bilinguals with brain injuries.

The current literature on language impairments following brain injuries is based on a disproportionately monolingual population (Grosjean, 1989; Hull & Vaid, 2007). The research on language impairments following brain injuries is based primarily on monolinguals (Grosjean, 1989) with injuries to language areas of their brain, the left hemisphere (LH). These brain injuries commonly result in aphasia (Darley, 1975). However, it is known that for bilinguals with (LH) injury the type and severity of aphasia is often different than that seen in monolinguals (Fabbro, 2001; Lorenzen & Murray, 2008). Right hemisphere (RH) injury is studied less than LH injury in both monolingual and bilingual populations (Brookshire, 2007). Just as there are differences in type and degree of language impairment between monolinguals and bilinguals with LH injury (Fabbro, 2001; Lorenzen & Murray, 2008; Paradis, 1999), there are potential distinct RH syndrome profiles as well. Given that some bilinguals with LH injuries are spared language impairments that their monolingual counterparts experience (Fabbro, 2001; Lorenzen & Murray, 2008; Paradis, 1999), could it be that some of their language functions are carried out by different parts of the brain, including the RH? If so, how might language then be impaired differently in bilinguals with RH injuries?

The aim of this research was to determine whether or not damage to the RH resulted in different levels of language deficits in monolinguals vs. bilinguals and within the bilingual population whether there were differences in impairment between the first language (L1) and second language (L2). In order to determine this, participants were assessed using the English and American Spanish short versions of the Bilingual Aphasia Test (BAT; Paradis & Libben, 1987; Paradis, 2011) and the Test of Nonverbal Intelligence (TONI-3; Brown, Sherbenou, & Johnsen, 1997).

Chapter Two: Literature Review

The Role of the RH in Language and Communication

The role of the RH in language processing has traditionally been thought to be rather unimportant in comparison to the dominant role played by its counterpart, the LH. However, the RH has a significant role in figurative, pragmatic, and cognitive aspects of language and its contributions are necessary for overall effective and efficient communication.

Research on neurologically typical individuals has revealed many roles of the RH in language. The RH is largely involved in understanding and producing appropriate stress, rhythm, and intonation in speech (Benowitz, Rosenthal, Mesulam, Zaidel, & Sperry, 1983; Cote, Payer, Giroux, & Joanette, 2007; Halper, Cherney, & Burns, 1996). The ability to comprehend and use these prosodic aspects of speech appropriately is critical to understanding and effectively using humor and sarcasm, other areas of language primarily governed by the RH (Benowitz et al., 1983; Jung-Beeman, 2005). The RH is dominant for processing figurative and metaphoric language, deriving themes, and assessing the significance of life events (Benowitz et al., 1983; Brookshire, 2007; Jung-Beeman, 2005). Perception of emotion and facial expressions are functions of the RH and critical for effective and appropriate communication (Benowitz et al., 1983).

Semantic tasks also activate portions of the RH. When presented with ambiguous or garden path variety sentences, the RH is responsible for constructing alternative interpretations and continually revising until a plausible conclusion is reached (Stowe, Haverkort, & Zwarts, 2005). As linguistic complexity increases, RH homologues of

Broca's and Wernicke's areas are increasingly recruited for processing (Stowe, Haverkort, & Zwarts, 2005).

These aspects of communication, prosody, non-literal, abstract, and metaphorical language, and facial expressions are critically important for effective communication. Furthermore, the RH is involved in fundamental cognitive aspects of language, including attention, memory, problem solving, orientation, and organization (Brookshire, 2007; Halper, Cherney, & Burns, 1996). The ability to maintain attention to a speaker in the presence of distractors, or switch attention back and forth between two speakers are necessary communication skills and dependent on a person's attentional abilities, which are controlled by the RH (Brookshire, 2007). These cognitive skills form the building blocks for language. Language, as an overarching system, requires the integration of attention, memory, reasoning, and organizational skills, along with the linguistic aspects of speech. Here we see the importance of the RH in communication coming in at both ends—in the preparation and generation of language via foundational cognitive linguistic skills as well as in the finishing touches that come from the pragmatic and social aspects it contributes.

Language Impairments as a Result of RH Injury

Of the population of individuals with RH injury, the majority have been shown to experience some form of communication disorder (Cote et al., 2007). Given the breadth of RH involvement in language and cognition, it is easy to see how injury to the RH could result in many forms of communication deficits. As a group, individuals with RH injuries are more heterogeneous than those with LH injuries, although it is possible that the reason for this is because individuals with RH injuries are often studied as an entire group whereas individuals with LH injuries may be classified into smaller more homogenous groups (e.g., Broca's and Wernicke's aphasia) (Tompkins, 1995), and thus it is easier to see patterns in symptoms associated with more specific lesion sites.

Individuals with RH brain injuries often experience a variety of deficits in their communication abilities. Pitch, rate of speech, organization, and topic maintenance and relevance may all be impacted as a result of RH injury. Additionally, the pragmatic aspects of language, the ability to follow social rules of conversation, including appropriate initiation and termination of conversations, understanding humor, and figurative language are all affected by RH injury (Brookshire, 2007; Jung-Beeman, 2005). The pattern of language deficits seen in RH brain injuries contrasts with those seen in LH injuries. For those with RH injuries, the structures of language, morphology, phonology, syntax, and lexical semantics, are less likely to be impaired, but rather the appropriate use and social aspects of communication are affected.

In one study of 28 individuals with RH injury, four distinct impairment profiles were found with respect to the areas of language assessed: prosody, lexical-semantic relations, pragmatics, and discourse. Of the 28 individuals, only three maintained globally normal abilities. The rest demonstrated deficits in all or some of the above areas (Cote et al., 2007). In comparison to individuals with LH injuries and control subjects with no brain injuries, those with RH injuries showed significant positive correlations between cognitive and verbal test scores (Zaidel, Kasher, & Batori, 2002), indicating that the degree of deficit in the verbal abilities assessed went hand-in-hand with the degree of cognitive impairment, suggesting a relationship between the two skills. Individuals with RH injuries also performed significantly worse than control subjects on metaphor, inferencing, humor, semantic, and discourse tests, as well as scoring poorer than those with LH injuries on the metaphor picture, inferential meaning, and discourse rating tests (Bryan, 1988). Meanwhile, those with LH injuries performed worse than those with RH injuries on the Western Aphasia Battery, an aphasia assessment measuring deficits in the structures of language across all four modalities (WAB; Kertesz, 1982; Bran, 1988). In these studies, injury to the RH spared the linguistic aspects of language that are assessed in the WAB and other aphasia tests. Participants with RH injuries scores were similar to those of the control group. However, for those with RH injuries pragmatic, figurative, metaphorical and abstract language were more impacted than in individuals with LH injuries.

The evidence from neurologically typical individuals as well as those with RH injury provides a clear view of the role of the RH in language. Its functions are varied and injury to the RH can result in a variety of impairment profiles. While injury to the RH undoubtedly affects pragmatic, figurative, metaphorical, and abstract language, it will not result in deficits to the formal aspects of language, namely: morphology, phonology, syntax, and concrete lexical semantics (Halper, Cherney, & Burns, 1996). Deficits to these aspects of language arise after injury to the LH and resulting aphasia, at least in monolinguals.

Aphasia as a Result of LH Injury

Damage to language areas of the brain result in a variety of profiles and impairments. Aphasia is a singular deficit in language, unrelated to other sensory, motor, or cognitive deficits, and thus is found when the areas of the brain responsible for language are damaged (Darley, 1982).

Initial lesion studies by Broca (1861) and Wernicke (1874) revealed the importance of the perisylvian area within the LH and the separation of different language functions within the perisylvian area (Geschwind, 1970; Ojemann, 1991). Lesion studies as well as research on neurologically typical individuals have shed light on both the existence of a core essential language area, the perisylvian area within the LH, as well as demonstrated the activation of widely dispersed neurons or supporting systems within both the left and right hemispheres for different language functions (Ojemann, 1991; Lucas, McKhann, & Ojemann, 2004).

Research on the LH as the dominant hemisphere for language has been based on a subset of the world's population, namely, monolinguals (Grosjean, 1989; Hull & Vaid, 2007). In order to be able to accurately apply the same conclusions to bilingual populations, systematic and comprehensive research must be carried out, evaluated, and used to determine whether the same conclusions hold true for multilinguals.

Historically, the vast majority of research on aphasia has come from monolinguals, while a few exceptional bilingual cases have often been thought to be representative of the bilingual population as a whole (Grosjean, 1989; Hull & Vaid, 2007; Paradis & Libben, 1987). However, if bilingual brains are organized and function differently with respect to language and thus have different language areas, the types of injury that may lead to language impairments may be different for bilinguals than monolinguals. Furthermore, damage to homologous areas of monolingual and bilingual brains may produce different patterns of language deficits in bilinguals than seen in monolinguals. In order to gain a full understanding of the bilingual brain, systematic and extensive research must be carried out rather than drawing conclusions based upon anecdotal research.

Language Impairment Following RH Compared to LH Injury

It is clear that communication in its totality is affected as a result of injury to either hemisphere. Injury to the RH causes impairments that broadly impact communication more than the formal aspects of language. The social aspects of language, or pragmatics, including prosody, non-literal language, and facial expressions may be impacted after injury to the RH (Benowitz et al., 1983; Brookshire, 2007; Cote et al, 2007; Halper, Cherney, & Burns, 1996; Jung-Beeman, 2005), while formal aspects of language morphology, phonology, syntax, and concrete lexical semantics remain intact (Halper, Cherney, & Burns, 1996). The reverse is true when the LH is injured. Individuals may have deficits in naming, verbal fluency, auditory and/or reading comprehension, repetition, and syntax (Brookshire, 2007).

A telling example of the differences in communication impairments seen between individuals with right and left hemisphere injury can be observed in their responses to the same picture description task. When presented with the *Cookie Theft* picture from the Boston Diagnostic Aphasia Examination (BDAE; Drawing from Goodglass, Kaplan, & Barresi, 2001), an individual with a RH injury provided the response below.

> "Well, this is a scene in a house. It looks like a fine spring day. The window is open. I guess it's not Minnesota, or the flies and mosquitos would be coming in. Outside I see a tree and another window. Looks like the neighbors have their windows closed. There's a woman near the window wearing what appears to be an inexpensive pair of shoes. She's holding something that looks like a plate. On the counter there, there's a hat and two caps that look like they would fit on a child's head. The woman is looking out the window, and the water's on, and it's running on the floor. Looks like she needs to call the plumber." (Brookshire, 2007, p. 409).

Several patterns typical of individuals with RH injury are evident in this response. The narrative is unorganized and lacks cohesion, many of the comments are tangential, and the picture is not described as a whole, but rather, small, incidental details are recounted. Furthermore, the participant later has to be prompted by the clinician in order to describe the previously unattended left side of the picture (see Appendix A). Overall, however, the language appears to be relatively intact. The sentences are complete and grammatically correct and no word errors or word finding troubles are seen.

A response to the same picture description task by an individual with LH injury, characterized by Broca's aphasia is presented below.

> "Wife is dry dishes. Water down! Oh boy! okay. Awright. Okay . . . Cookie is down . . . fall, and girl, okay, girl . . . boy . . . um . . . Cookie is . . . um . . . catch Girl, girl! Boy . . . fall down! Wife is dry dishes. Water down! Oh boy! okay. Awright. Okay . . . Cookie is down . . . fall, and girl, okay, girl . . . boy . . . um . . . Cookie is . . . um . . . catch Examiner: Girl, girl! Boy . . . fall down!" (Avrutin, 2001, p. 87).

Here, the structures of language are clearly impaired. No more than a few words are strung together at a time. The sample contains primarily nouns with very few verbs and fewer prepositions. Clear deficits in verbal fluency, naming, and syntax are evident. However, the participant here, even given the limited verbal response, addresses the major aspects of the picture as a whole more completely than did the individual with a RH injury.

It is clear from the above examples that both RH and LH injuries impact communication and language, but in very different ways. The contributions made by each hemisphere to communication overall are seen in the above examples as well as the necessity of each for effective and efficient communication. In terms of communication, it is the two halves that make the whole.

While the roles of each hemisphere and their contributions to communication and language appear irrefutable, it is important to go back and think of the population this research was based upon. Given the rise and current proportion of the population that speaks more than one language (U.S. Census Bureau, 2011), it is necessary to step back and examine whether or not the same conclusions drawn from monolingual populations can be generalized to multilinguals. Research on bilinguals with LH injury and resulting aphasia has demonstrated that this is not always the case (Fabbro, 2001; Lorenzen & Murray, 2008; Paradis, 1999).

Bilingual Aphasia

The type of aphasia found in monolinguals is clearly correlated with the location and extent of damage to language areas in the brain (Geschwind, 1970). Monolingual aphasia can be typed and classified with high levels of accuracy using standardized assessments such as the BDAE (Goodglass, Harold, & Kaplan, 1983). However, classifying bilingual aphasia is more complicated. A large proportion of bilinguals experience language dysfunction after brain injury in a similar manner as monolinguals. However, for some bilinguals, both languages cannot be neatly accounted for using the monolingual framework (Fabbro, 2001; Lorenzen & Murray, 2008), and for this population, a further explanation is needed. A lesion to the same language area as a monolingual may result in either the same type of aphasia for a bilingual's L1 and L2, spared preservation of either language, or greater deficits in either.

A 2008 position statement put forward by the American Speech-Language-Hearing Association (ASHA) provided a review of research on bilingual aphasia. The research revealed that the majority of bilinguals with aphasia experience parallel injury in which both languages are impacted equally, and thus fit a dual monolingual language impairment model. However, a significant number of bilinguals experience asymmetrical language dysfunction in which one language is more impacted than another, unpredicted by premorbid status (Lorenzen & Murray, 2008). In a study assessing 20 bilingual Friulian-Italian aphasics using the Bilingual Aphasia Test (BAT; Paradis & Libben, 1987; Paradis, 2011), differences in impairment between L1 and L2 were found within patients in the group. All patients presented with aphasia following LH lesions. The results were in agreement with the results put forward by ASHA. It was found that the majority, 65% of individuals, experienced parallel injury in L1 and L2, whereas 20% had greater impairment in L2, and 15% were more impaired in their L1 (Fabbro, 2001).

For the 35% of bilinguals whose language impairment did not follow a dual monolingual model, some explanation is needed. Many theories and hypotheses regarding the cerebral organization of language in the bilingual brain have been put forward in attempts to explain differences between monolingual and bilingual language representation.

Hypotheses on Representation of L1 and L2 Within Bilinguals

The LH is known to be the dominant hemisphere for language in the vast majority of individuals (Knecht, Drager, Bobe, Lohmann, Floel, Ringelsteain, & Henningsen, 2000). However, much of the known research on hemispheric dominance of language comes from studies on monolinguals (Hull & Vaid, 2007). The involvement of the RH in the formal aspects of language and different lateralization of L1 and L2 in bilinguals is a highly researched and debated topic (Paradis & Libben, 1987). The extent to which, if at all, the RH is involved in language for bilinguals is theorized and discussed in the following four hypotheses.

The *redundant participation hypothesis* proposes that both hemispheres process linguistic information: the LH to a greater extent, making the RH effectively redundant. Thus, any damage to the RH would have relatively little impact on language overall. According to this hypothesis, bilinguals with RH brain injuries would not demonstrate any linguistic deficits because the functions that may have been carried out by the area of RH injury are also carried out, and to a greater extent, by the LH, while injury to the LH would result in severe linguistic impairments.

The *quantitatively complementary participation hypothesis* states that each hemisphere processes the same information in the same way, with the LH still having a greater total effect. There is a sum total necessary however, that requires the input of both hemispheres. A lesion to a homologous area of the left or right hemisphere will cause identical deficits. According to this hypothesis, a lesion to the RH would result in some amount of deficit overall as the input from both the LH and RH are necessary for the whole.

The *qualitatively parallel participation hypothesis* suggests that the same stimuli are processed by both hemispheres but in different ways qualitatively. Each hemisphere fully processes information in its own way, thus the participation of the RH is qualitatively complementary to that of the LH with respect to each aspect of an utterance. Therefore, damage to either the left or right hemisphere would affect their respective component parts of an utterance. Here we may see that the RH processes the tone of a word while the LH processes the meaning.

Finally, the *qualitatively selective participation hypothesis* is similar to the qualitatively parallel participation hypothesis, but here the different processing by the LH and RH are complementary with respect to the utterance as a whole (Paradis & Libben, 1987). Using the same example as above, in this hypothesis, the RH may be processing the tone of a conversation while the LH processes the syntactic structure.

The four hypotheses above cover a broad spectrum of theoretically potential RH involvement in language within the bilingual brain. In addition to debate over the extent of involvement and degree of participation of the RH, the degree of overlap or separation of the neural representation of L1 and L2 is also often discussed in the literature. Four additional hypotheses regarding the structure and organization of the two languages within the bilingual brain are discussed below.

In *The extended systems hypothesis*, a bilingual's two languages are undifferentiated in their cerebral representations. There are more morphemes, phonemes, syntactic rules, and words, and each are used in their own context. L2 is not represented differently than L1, but rather the two languages overlap fully. According to this theory, a lesion to a language area of the brain would affect L1 and L2 in the exact same way.

The *dual system hypothesis* proposes that each language is stored separately. There are two systems for every aspect of language, and each language is independent of the other, according to this hypothesis. The dual system hypothesis suggests that a lesion to a language area of the brain, which includes the RH, would result in damage to only the language supported by the lesion area. In this hypothesis, the language areas of the brain that support L1 and L2 are anatomically separate, and thus a focal injury would only ever impact the single language associated with that region.

The *tripartite system hypothesis* suggests that shared functions or concepts of a language are represented together and what differs between each language is represented separately. Thus, if the sentence structure of L1 and L2 are similar, then sentence structure will be represented in the same area of the brain for L1 and L2, just as in the extended system hypothesis. However, the lexicon for each language must be distinct and thus each would be represented separately, as in the dual system hypothesis. In this hypothesis, there are three representations of language within the bilingual brain—a shared overlapping area as well as two distinct L1 and L2 representations. Thus injury to a language area of the brain could result in deficits in L1 and L2 or in only one language depending on whether the injured area housed shared or distinct languages.

Finally, *The subset hypothesis* allows that the extended and dual systems hypotheses are not mutually exclusive. Rather, both languages are stored in identical ways in a single overarching cognitive system. Because elements of each language normally appear in different environments, they form two different systems and networks and thus subsystems within a larger system. Bilinguals have two subsets of neural connections, one for each language, and they can be activated or inhibited independently. At the same time, they possess one larger set from which they can draw elements of either language at any time (Paradis & Libben, 1987).

These hypotheses provide theoretical explanations for the variability in L1 and L2 deficits seen in bilinguals with aphasia. The majority of bilinguals with aphasia who experience parallel injury can be accounted for by the extended system hypothesis. Nonparallel injury may be explained by the dual system hypothesis or the tripartite system hypothesis, depending on the profile of deficits, only one language, or some unequal combination in both L1 and L2. The subsystem hypothesis seems potentially capable of accounting for the variability seen in all types of bilingual aphasia (Fabbro, 2001; Lorenzen & Murray, 2008; Paradis & Libben, 1987;). However, it is important to remember that while the above hypotheses attempt to explain differences seen between monolinguals and bilinguals, theoretically they do not provide any behavioral or neurological evidence to account for the variability.

Given an understanding that bilinguals may experience a variety of language deficit profiles following a brain injury and that there are various hypotheses that attempt to account for the variability seen in the bilingual aphasia population after LH injury, the next question to be considered is: What does language impairment in L1 and L2 look like in bilinguals with RH injury?

Evidence for RH Involvement in Linguistic Aspects of L2

Evidence from both neurologically typical and atypical bilinguals has demonstrated greater RH involvement in the structures of language for L2 than seen in either L1 or in monolingual populations (Ding et al., 2003; Hull & Vaid, 2007). In two meta-analyses of 66 behavioral studies, a clear RH involvement and bilateral activation was seen in all language tasks for bilinguals, and a strong correlation between age of acquisition of L2 and degree of RH involvement was found (Hull & Vaid, 2007).

In orthographic and semantic judgment tasks, consistently greater RH activation was seen when participants were using their L2 but not for L1 (Ding et at. 2003). In this study, the age at which participants acquired their L2 was between 11-13 years, beyond the early age of acquisition cutoff found as a determining factor by Hull and Vaid (2007), and older than the age at which potential L2 proficiency has been shown to reach a ceiling (Johnson & Newport, 1989). In this case, there was a clear increase in RH involvement in aspects of language the RH was not involved in for L1 processing.

Research from WADA tests (Breier et al., 1996; Gomez-Torotosa, Martin, Gaviria, Charbel, & Ausman, 1995; Kho, Duffau, Gatignol, Leijten, Ramsey, van Rijen, & Rutten, 2007) demonstrate the role of each hemisphere in language tasks of bilinguals. In a WADA test, sodium barbiturate is injected into one of the internal carotid arteries one hemisphere at a time in an attempt to shut down, and thereby discover, whether language and memory are controlled by that hemisphere. In these tests, only one hemisphere is active at a time, so any deficit observed can be causally linked to the inactive hemisphere. For LH dominant individuals, injection of the sodium barbiturate into the left internal carotid artery should result in a global aphasia and injection to the right internal carotid artery should leave language skills unimpaired. Several results from WADA tests carried out on bilingual patients reveal a different pattern of deficit following injection into one or the other hemisphere. Upon injection of barbiturate into the right internal carotid artery, a bilingual Spanish (L1)-English (L2) patient spontaneously switched from performing a language task in his L2 to his L1. After injection to the left internal carotid artery the patient was globally aphasic (Breier et al., 1996). This patient was strongly right handed dominant as determined by the Crovitz-Zender Handedness Questionnaire (Crovitz & Zener, 1962).

Other results from WADA tests have also shown atypical hemispheric dominance for L2 within bilinguals (Gomez-Torotosa et al., 1995; Kho et al., 2007). However, in reported cases, only one or two patients are reported on and premorbid factors are not controlled for nor are assessment procedures equivalent. Care must be taken in the interpretation of these anecdotal cases and generalizations cannot be drawn from them. However, they are in agreement with other evidence taken from larger populations regarding bilingual language laterality and increased RH involvement for L2 and thus as a whole a trend of increased RH involvement for L2 is visible.

Clinical Implications

We know some about what happens to bilinguals with LH injury in terms of bilingual aphasia, but the current knowledge regarding what happens to bilinguals with RH injury is varied and it is difficult to discern solid patterns. The research on interhemispheric organization of L1 and L2 in bilinguals demonstrates that there is currently a lack of consensus on how and why bilinguals' language organization differs from monolinguals. However, the research does suggest that bilinguals employ, to varying degrees, different systems for L1 and L2. The degree of anatomical separation between the two languages may cause the two languages to be impaired differently following an injury to a language area in the brain, as demonstrated by research on neurologically typical and atypical individuals (Fabbro, 2001; Lorenzen & Murray, 2008; Paradis, 1999). It is crucial to understand potential organizational differences between L1 and L2 for bilingual patients with brain injuries in order to most effectively evaluate and treat the full scope of their language impairments.

The clinical implications of extended, dual, tripartite, or subset systems are varied. Theoretically, if the bilingual's languages are fully overlapped, a lesion to any language involved brain area will affect their L1 and L2 in a mirrored manner. Conversely, if the two languages have different loci, networks, or regions of activation, a focal lesion may affect each language differently or one language not at all. Evidence from neurologically atypical bilinguals sheds some light on how the interhemispheric differences between L1 and L2 affect bilinguals' language abilities after a RH brain injury.

To further add to the growing body of research on language differences in bilinguals after RH brain injury, this study compared monolingual English speakers and bilingual Spanish-English speakers' performances in their first and second languages, using the short version of the English and American Spanish BAT and the Test of Nonverbal Intelligence (TONI-3; Brown, Sherbenou, & Johnson, 1997). Results were compared and analyzed in order to observe whether there was a different pattern of deficits between monolinguals and bilinguals and further if bilingual's L1 and L2 were impacted differently after a RH injury as is suggested by the literature regarding interhemispheric bilingual language organization.

Chapter Three: Methodology

Participants

All participants were recruited from local Speech-Language Pathology (SLP) caseloads or area brain injury support groups in Southern California. Participants were recruited beginning in the summer of 2014, and recruitment continued until February 2015. Recruitment materials were provided in English and Spanish below a high school reading level. Potential participants were asked if they were interested in participating and able to meet the criteria of the study. If so, they were asked to contact the investigator. Participants were either self-referred or asked if interested in participating by an SLP. Participants or their referring SLP informed the investigator of whether or not the participant was monolingual or bilingual.

Participants were required to meet the following criteria: 1) be either a monolingual English speaker, or a bilingual Spanish and English speaker; 2) have had a RH brain injury (excluding traumatic brain injuries); 3) be right handed; and 4) have no premorbid history of language, cognitive or developmental disorders, or other significant medical history. Participants self-reported whether or not they were able to meet the above inclusion criteria. When issues arose because participants did not meet all aspects of the criteria, the investigator made the decision as to whether or not it was appropriate to assess and include their data.

A total number of six participants were included the study; four monolinguals and two bilinguals. The two groups were a monolingual group made up of four monolingual speakers with RH injuries and a bilingual group with two Spanish-English bilinguals.

One monolingual participant's data was not included; at the point of assessment the acuity of illness appeared to exacerbate any RH deficits and therefore results would likely not have been indicative of RH impairment but her general deficits at that time. The participant was unable to establish a reliable yes-no response and so the assessment was discontinued. The majority of the participants' RH injuries were cerebrovascular accidents (CVAs), one participant had an anteriovenous malformation (AVM) and one had a colloid cyst. All the participants injuries were limited to the RH, thus as there was no LH involvement language impairments could be fully attributed to RH functions. One participant was left-handed, and one stated he was ambidexturous. However, he completed all assessment related tasks with his right hand as well as saying that he had previously used his right hand for writing. Prior relevant history for all participants was limited to one unofficial diagnosis of attention deficit disorder (ADD) and one bilingual participant who was not literate in their L2. The above deviations from inclusion criteria were not deemed to be confounding in the overall goal of observing the effects of RH injury on language impairment for L1 and L2 of bilinguals compared to monolinguals and therefore participants were included in the study. See Table 1 for further participant demographics.

The first bilingual participant (B1) was an early-acquired bilingual. He learned both his L1 and L2 from birth. The second bilingual participant was a late-acquired bilingual. She learned her L2 at 20 years of age and was not literate in the language. Both participants considered themselves bilingual and used both English and Spanish in their daily lives prior to their injuries. The bilingual participants also differed in what they considered their L1 and L2. Although B1 learned both Spanish and English from birth he considered English to be his L1. B2 learned Spanish first and English at age 20 when she moved to the United States. Her L1 was therefore Spanish.

Design

This study employed a single-subject design. Two groups were used to determine if: 1) L1 impairments in bilinguals were the same as those seen in monolinguals and 2) bilingual Spanish-English speakers with RH injuries had significant differences in the L1 and L2 scores on the short versions of the American Spanish and English BAT.

Table 1: Participant demographics

Participant	**Diagnosis**	**Language(s) spoken**	**Handedness**	**Prior history**
B1	R AVM	English (L1), Spanish (L2)	R	ADD
B2	R CVA	Spanish (L1), English (L2)	R	Illiterate in L2
M1	R CVA	English	R	None
M2	R CVA	English	R	None
M3	R CVA	English	R	None
M4	R colloid cyst	English	R, ambidextrous	None
M5*	R CVA	English	L	None

*Participant data was not included, assessment was not finished.

Setting

All assessments were conducted at convenient locations for the participants, such as the university clinic or locations in or near the participant's residence. Given varying levels of mobility, some accommodations were made for participants, including conducting assessments in their bed, moving the stimulus items so they were always within the right half of the participants' visual field, and for two participants test items requiring reading and writing were eliminated. One participant was illiterate in the language of assessment and the other had visual attention deficits the precluded them from being able to complete those items.

Materials

All of the participants were asked to complete a short case history prior to beginning the assessments. In addition to the criteria listed above, the case history asked for the date of RH injury. The length of time between the injury and date of assessment (status post) was later computed. Given the natural recovery that has been shown to occur in language deficits following a brain injury (Wade, Hewer, David, & Enderby, 1986), the status post variable was used to observe to what degree language impairments seen on the BAT were correlated with length of time since injury.

The short versions of the English and American Spanish BAT were used to obtain comprehensive measures of the participants' language abilities. The American Spanish version of the BAT was designed for use with Spanish speakers from Latin America and thus was a more appropriate version for the Spanish speaking population in Southern California than the European Spanish version. The short version was administered in lieu of the complete version of the BAT due to predicted attentional issues that may prohibit this population from performing reliably on a multi-hour assessment. The BAT contains three sections. Part A includes questions about language use history including age of acquisition, parents language use, formal educational use, and home use for L1 and L2.

These questions were not asked of monolingual participants as the questions were designed to provide information about multilinguals language history. The short version of part B consists of 245 items which were used to evaluate the participants' language abilities. The BAT examines language performance in all four modalities in each of the languages a participant speaks. The specific purpose of the test is not to measure communicative skills but rather specific linguistic abilities. The short version reveals potential deficits in a particular area of language (e.g. comprehension, lexical access, repetition, phonology, syntax, and semantics). Part C was not used in this study but is a language pair test in which participants are asked to translate back-and-forth between two languages for two investigators.

The BAT is available in over 65 languages and tests are not simply translations but rather they are equivalent assessments with respect to cultural and linguistic appropriateness. The purpose of the BAT is to determine whether one language is more impacted than another. It is constructed so as to measure discrepancies in language disorders not language differences. For example, item 56 asks the participant to touch the picture of the word being read aloud by the investigator. In the English version, the four words are: clip, drip, slip, and ship. Thus, it is a test of the participant's ability to discriminate between words that differ by only one sound or sound cluster. A direct translation of these test words to Spanish is: clip, gotear, resbalar, y barca. The direct Spanish translations would clearly not be a valid way to assess auditory discrimination. Additionally, the translated words do not necessarily have the same frequency of use as the original English words, which would further invalidate the Spanish version as an equivalent test item. In the American Spanish version of the test, the words for item 56 are: beso, hueso, queso, y peso, equivalently high frequency words which differ by a single sound.

In addition to the BAT, participants were assessed using the Test of Nonverbal Intelligence (TONI-3; Brown, Sherbenou, & Johnson, 1997). The TONI-3 is a language free measure of an individual's ability to complete abstract and spatial reasoning tasks. Instructions were modeled gesturally rather than recited verbally, according to the administration procedures outlined in the manual. In this way there was no linguistic interference. This test is appropriate for individuals from culturally and linguistically diverse backgrounds as well as those with neurological impairments. As discussed above, many cognitive-linguistic skills are governed by the RH and injury to the RH may cause language impairment as a result of these cognitive deficits. In order to separate language deficits due to cognitive impairments from potential additional deficits resulting from increased RH involvement in bilinguals the TONI-3 was used. This test was selected to provide a rough baseline of the participants' nonverbal intelligence, in order to determine whether performance on language tasks (the BAT) were correlated with the degree of cognitive deficit as measured by the TONI-3. The use of both the BAT and the TONI-3 allowed for the results to be analyzed in terms of language deficit variability based on cognitive deficit.

Procedure

As participants were recruited, they were assessed in the several ways. Monolingual participants had one assessment session with the investigator. The session began with the investigator completing a brief case history. After the case history, all participants were assessed using the short version of the English BAT. A language sample was the first task of the assessment and in order to ensure a standardized response all participants were given a picture of the *Cookie Theft* (Goodglass, Harold, & Kaplan, 1983) and were asked to provide a description while the investigator audio recorded their response. The short version of the English BAT was completed in its entirety for all monolingual participants. Following the BAT, all participants were assessed using the TONI-3. All monolingual assessment sessions and the first session for bilinguals lasted approximately 1 hour. The second assessment session for bilinguals was shorter and generally took about 45 minutes.

Bilingual participants had two assessment sessions with the investigator. Half of the bilingual group was assessed first in their L1, while the other half was assessed first in their L2. This controlled for test familiarity and any L1 or L2 biases based on order of assessment. Prior to beginning each session, the investigator asked someone to remind the participant that the investigator would be speaking in only English or only Spanish. In order to replicate a monolingual environment as closely as possible for each session, the investigator spoke only in the language of assessment and reminded and encouraged the participant to do so as well.

The first assessment session for the bilingual group was identical to that of the monolingual assessment session, with the exception that half of the first sessions for the bilingual group were conducted in their L2. The second assessment session for the bilingual group included only the version of the BAT not used in session one. Since the TONI-3 is a test of nonverbal intelligence and no verbal instructions were given, the investigator determined that there was not a bias due to whether the bilinguals were assessed on the TONI-3 following their L1 or L2. For some participants, follow-up and clarifying questions regarding their case history were asked in the second assessment session.

The investigator transcribed the participants' responses from the spontaneous speech task and entered all scores following the assessment sessions.

Analysis

Total scores were calculated as a percent correct. As one participant was illiterate and one had visual deficits that precluded him from completing reading and writing tasks, two participants did not complete all of the reading and writing test items and their total number was adjusted. The overall number of quantitatively measureable test items on the short version of the BAT was 236. Results were analyzed using linear regressions in Minitab (2010). Results based on performance on individual subtests were analyzed visually.

Chapter Four: Results

The type and number of subtests on the BAT in which participants scored below the normal range are presented in Table 2. Proportionally, the bilingual participants scored below the normal range in more subtests than any of the monolingual participants. Two of the participants, B2 and M3, were unable to complete reading and writing subtests on the BAT. These participants each completed 12 out of the 20 subtests. The proportion of subtests in which participants were below the normal range is listed in Table 2. B1 was below the normal range in 13 out of 20 subtests in his L2. B2 was below the normal range in 11 out of 12 subtests in her L2. Monolingual scores on the BAT ranged from 95-63%. For monolingual participants degree of language deficit was directly correlated with TONI-3 scores as well as length of time since injury.

The bilingual participants both scored much lower on the BAT in their L2 than their L1. B1 had an overall score of 95% in his L1 and a score of 75% in his L2. B2 had a score of 78% in her L1 and a score of 38% in her L2. There was a gap of 20% and 40% respectively between the L1 and L2 scores of the bilingual participants. All participants' percentage scores are displayed below in Table 3.

All participants' BAT scores were analyzed in response to two variables: 1) TONI-3 scores and 2) their status post injury. As discussed earlier, RH injuries are associated with deficits in the cognitive skills that are necessary for language as a whole. In brain injuries, there is a degree of natural recovery that occurs following injury (Wade et al., 1986). As the goal of this research was to see if bilinguals had language deficits in their L2 beyond the cognitive-linguistic deficits seen in monolinguals with RH injuries, BAT scores were compared against TONI-3 scores. The degree to which TONI-3 scores

Table 2: BAT subtests within or below normal range

SUBTEST	**B1L1**	**B1L2**	**B2L1**	**B2L2**	**M1**	**M2**	**M3**	**M4**	**TOTAL**
Pointing	0	1	0	1	0	0	1	1	4
Simple Commands	0	0	0	1	1	0	0	0	2
Semi complex Commands	0	1	0	0	0	0	1	0	2
Verbal Auditory Discrimination	0	0	1	1	1	0	1	0	4
Synonyms	0	1	1	1	0	0	0	0	3
Antonyms	0	0	1	1	1	0	0	0	3
Judgment	1	1	1	1	1	1	1	1	7
Sentence Repetition	0	1	1	1	0	0	0	0	3
Series	0	1	0	1	0	0	0	0	2
Naming	0	1	1	1	1	0	1	0	5
Sentence Opposites	1	1	0	1	1	0	1	0	5
Listening Comprehension	0	0	0	1	0	0	0	0	1
Reading(words)	0	0	0	N/A	0	0	1	0	2
Reading (sentences)	0	1	0	N/A	0	0	N/A	0	3
Reading (text)	0	1	0	N/A	0	0	N/A	0	3
Copying	0	0	1	N/A	0	0	N/A	0	3
Dictation(words)	0	1	0	N/A	0	0	N/A	0	3
Dictation (sentences)	0	1	0	N/A	0	0	N/A	0	3
Reading Comprehension (words)	0	1	1	N/A	0	0	N/A	0	4
Reading Comprehension (sentences)	0	0	0	N/A	1	0	N/A	0	3
Proportion of subtests below normal range	2/20 =.1	**13/20 =.65**	8/20 =.4	**11/12 =.92**	7/20 =.35	1/20 =.05	7/12 =.58	2/20 =.1	

1 = score below normal range, 0 = score within normal range

Table 3: BAT scores for all participants

	B1	B2	M1	M2	M3	M4
BAT L1	95.76%	78.39%	79.66%	93.31%	63.43%	95.34%
BAT L2	75%	38.6%	---	---	---	---

Figure 1: BAT scores predicted by TONI-3 scores for all participants

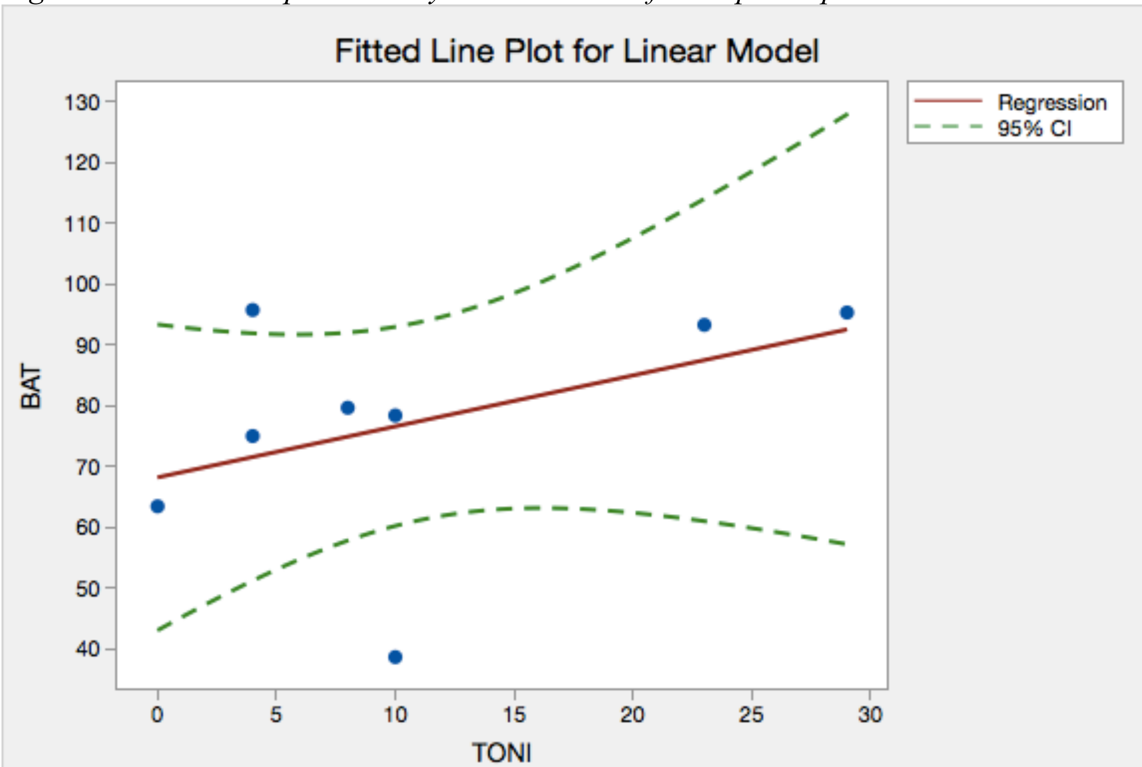
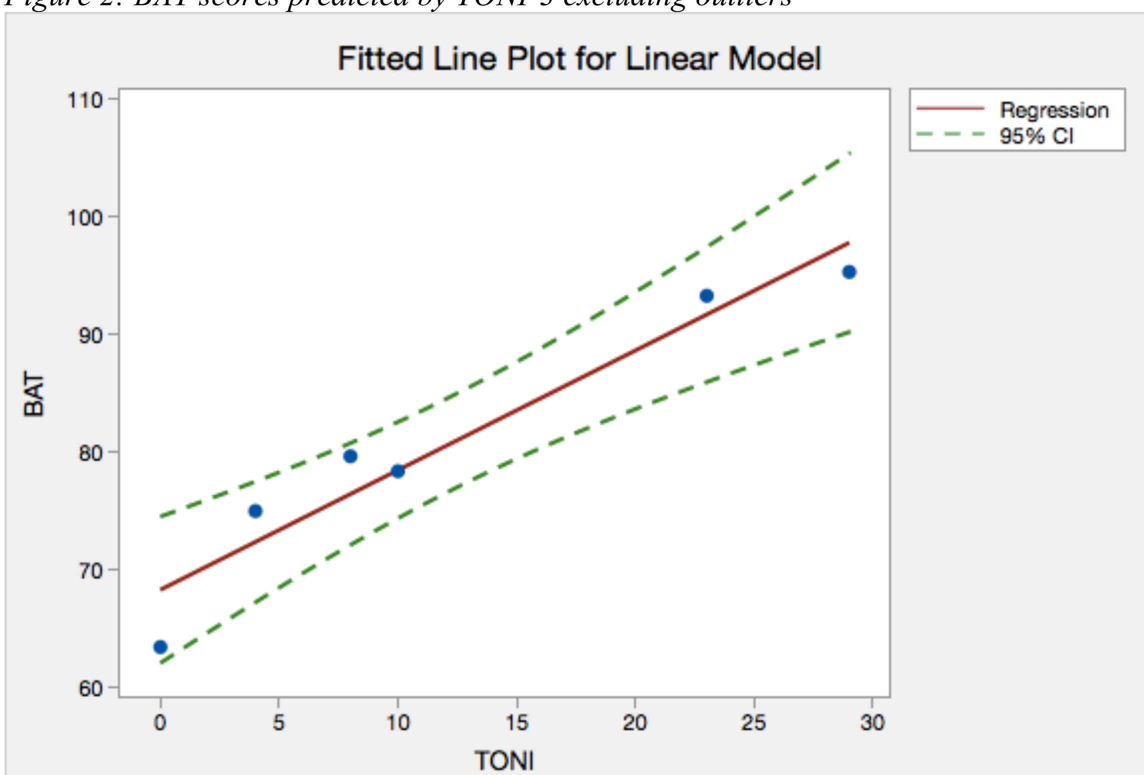


Figure 2: BAT scores predicted by TONI-3 excluding outliers



(cognitive deficits) predicted BAT scores (language deficits) for all participants is shown in Figure 1.

In Figure 1 there are two points that lie outside of the 95% confidence interval. The point above the confidence interval is the L1 score for B1, and the point below the confidence interval is the L2 score for B2. With the inclusion of all data points, TONI-3 scores do not predict BAT scores with a high level of accuracy. R-squared is 5.26%, thus only 5.26% of the variability in the BAT scores is explained by TONI-3 scores. The p-value of 0.2832, demonstrates that there is a high probability, 28.32%, that there is no relationship between TONI-3 and BAT scores when all the data points are considered.

The linear regression excluding the two outliers is shown in Figure 2. Eliminating the outliers yields an R-squared value of 91.26% and a p-value of 0.0019. In this analysis, TONI-3 scores were highly predictive of BAT scores. Additionally, the probability that there is no relationship between the two variables is very low, 0.19%. A strong positive correlation is seen between higher TONI-3 scores and better performance on the BAT.

Given the natural recovery that has been shown to occur following a brain injury, it was expected that participants who had experienced brain injuries more recently may have more significant deficits than those whose injuries occurred further in the past. In order to observe the degree to which BAT scores were affected based on length of time since injury a linear regression was carried out for these variables (see Figure 3).

In Figure 3, the same two outliers are seen. Accordingly, R-squared is low, 15.89%. In other words, status post injury is not highly predictive of BAT scores. The p-value, 0.204, is high, or the probability that there is no correlation between status post injury and BAT score is high. The length of time since the participant's brain injury does not predict their BAT scores, nor do the two variables appear to be related when all data points are included. When the outliers are not included in the analysis, the changes mirror those seen with the TONI-3 linear regression (see Figure 4). Here the R-squared value was 94.74%, and the p-value was 0.0034. In this regression, there is a strong positive relationship between the two variables. As the length of time since injury increases, the BAT score improves as well. The likelihood that the two variables are unrelated is very low, 0.3%.

Figure 3: BAT scores predicted by status post (s/p) injury for all participants

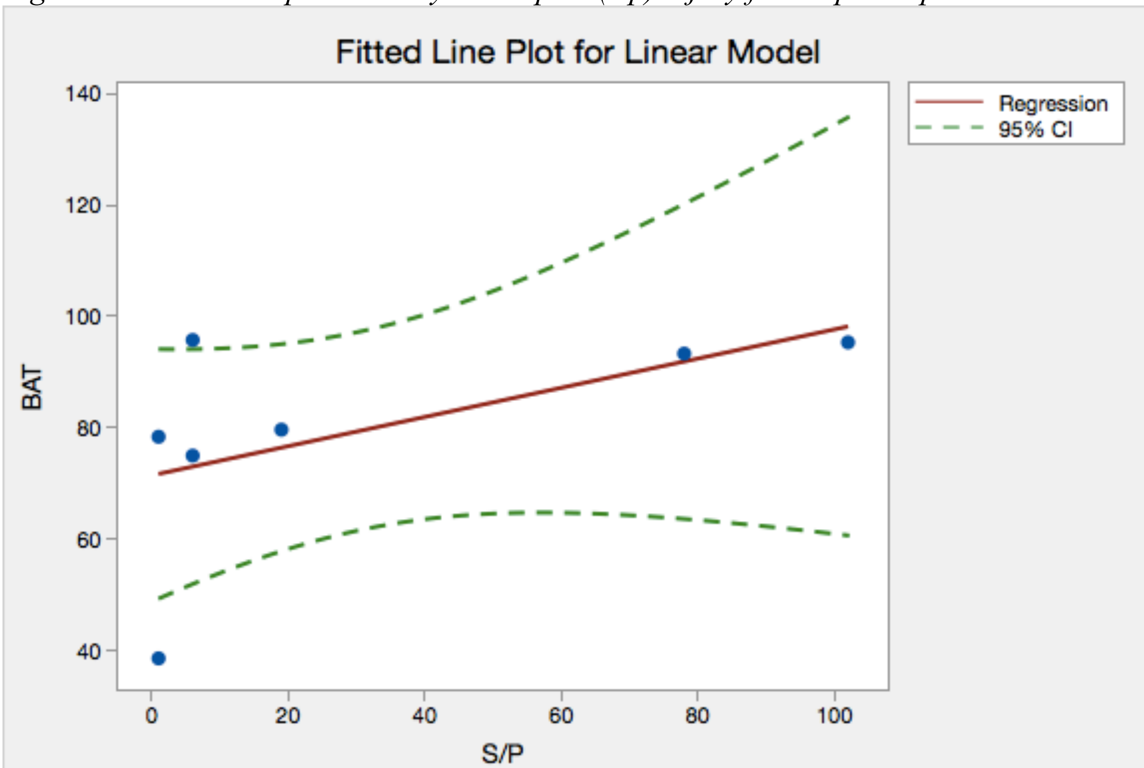
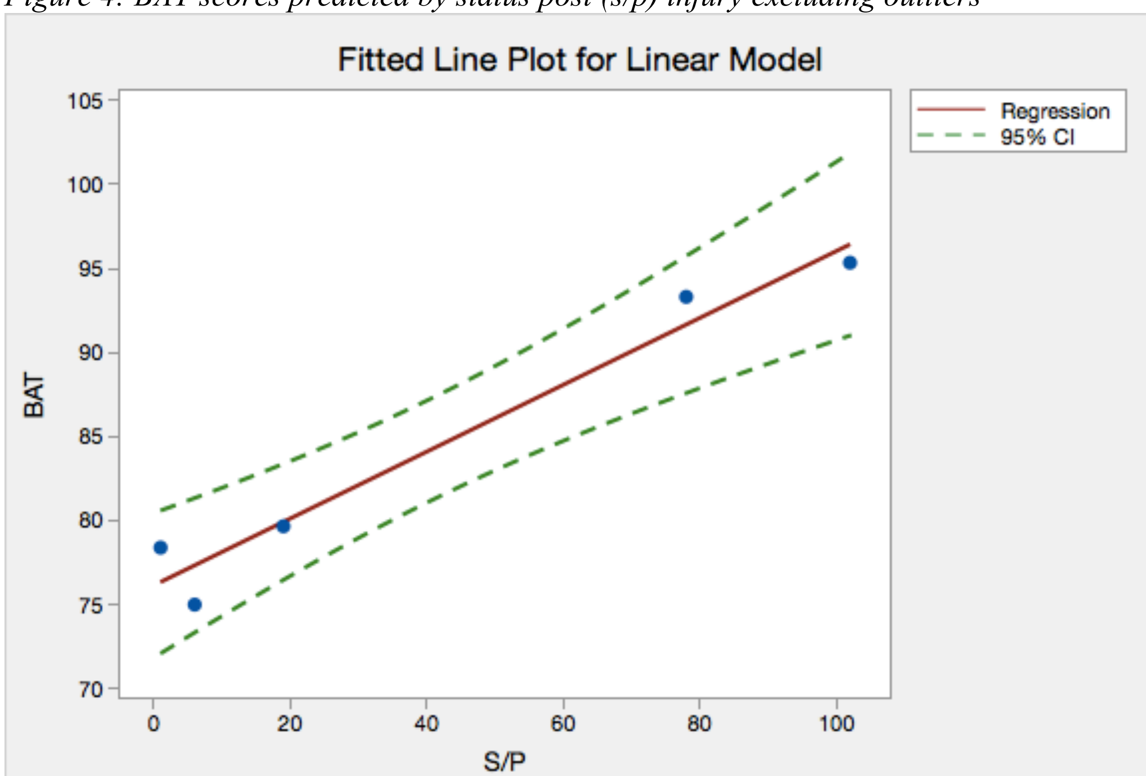


Figure 4: BAT scores predicted by status post (s/p) injury excluding outliers



Chapter Five: Discussion

Introduction

The purpose of this research was twofold. The first goal was to determine if RH injuries affected language the same way in monolinguals and bilinguals. Given the hypothesis that monolinguals and bilinguals would have differing language deficits, the next aim was to see if L1 and L2 were affected differently for bilinguals. In order to observe potential differences language test scores were compared against two variables, cognitive scores on the TONI-3 and the length of time since injury for all participants.

Summary of Results

TONI-3 scores and length of time since injury were thought to be highly predictive of the degree of language impairment for individuals with RH injury (Wade et al., 1986; Zaidel, Kasher, & Batori, 2002). If there were no differences between monolinguals and bilinguals all BAT scores should have fallen in line with the TONI-3 and status post linear regressions. However, the bilingual participants had significant differences between their L1 and L2 scores. Both participants scored lower in their L2. Thus, for both bilinguals neither linear regression predicted both their L1 and L2 BAT scores. In addition to scoring lower on the BAT in their L2, the bilingual participants also scored below the normal range on the largest proportion of subtests in their L2. The depth and breadth of their language deficits in L2 were greater than in their L1, or than for the monolinguals.

For the early-acquired bilingual his L2 BAT score was predicted by his TONI-3 score and status post injury while his L1 score was higher and outside of the 95% confidence interval for both linear regressions. The opposite was seen for the late-acquired bilingual. Her L1 score was in line with TONI-3 and status post linear regressions and her L2 score fell below the 95% confidence interval. For both bilinguals L2 scores were lower than L1 and more subtests were below the normal range in L2. However, whether or not the linear regressions predicted BAT scores in L1 or L2 was different for each. Whether or not this was due to age of acquisition or another variable cannot be discerned from the small sample in this research.

Implications

The clinical implications of these findings are important for professionals evaluating and treating language impairments bilinguals with RH brain injuries. The results demonstrate that bilinguals and monolinguals have different language impairment profiles following RH brain injuries and bilinguals have different degrees of deficit in their L1 and L2. The results show the crucial need to fully assess the language history and abilities for bilinguals in both languages, as it is clear that L2 deficits cannot be inferred based on L1 or based on monolingual populations. Assuming the bilinguals have equivalent language deficits in both L1 and L2 could lead to inadequate treatment of L2.

Limitations and Future Research

The results from this research demonstrate that for these bilingual Spanish-English participants a RH injury impacted their L2 more than their L1 and more than the language of monolinguals with RH injuries. There are several limitations to this research that prevent drawing broader conclusions and generalizations. First, the sample size is small and does not lend itself to particular statistical significance. There are many potentially confounding factors related to L1 and L2 language use and history as well as RH injury that were not controlled for in this research. Potentially relevant factors related to language use and history include, age of acquisition of L2, premorbid levels of proficiency, level and context of use for each language, as well as formal experience in each language.

Further, the research demonstrates mixed results regarding whether or not there may be differences based on which language is an individuals L1 vs. L2. The bilingual participants differed in whether Spanish or English was their L1. For neurologically typical Spanish-English bilinguals scores on the American Spanish BAT were lower than those on the English BAT (Munoz & Marquandt, 2008), while in other research the degree of RH lateralization did not appear to be impacted based on which language was an individuals L2 (Ding et al., 2003; Hull & Vaid, 2007). Other factors not controlled for related to participants' RH injury were the type, location, and extent of the injury as these have all been seen to differentially affect the degree of language impairment for individuals with LH injuries.

Future research with larger sample sizes may be able to more carefully control for the potentially confounding variables listed above. This could provide insight into whether degree of deficit in L1 and/or L2 may be predicted by any of the above variables. As is the case with bilingual language research in general, larger scale studies need to be completed in order to observe overall patterns of language impairment in bilingual populations.

Conclusion

The aim of this research was to determine if as a whole RH injury led to different language impairments in bilinguals L2 compared to their L1 and monolinguals. The results revealed that in this case both bilinguals had greater L2 deficits than L1 deficits and their language deficits could not be fully predicted by TONI-3 scores or status post injury as was true for monolinguals. Additionally, the bilinguals had deficits in a broader range of language skills in their L2 than they did in their L1 or than did their monolingual counterparts. Overall, the necessity of viewing bilinguals as unique from monolingual populations with respect to language impairment following RH injury is clear.

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Appendix A: Cookie Theft Picture Description