COGNITIVE DEFICITS IN CHRONIC STROKE SURVIVORS

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

UNIVERSITY OF FLORIDA

2010

To my endlessly supportive husband and family

ACKNOWLEDGMENTS

The completion of this project could not have been accomplished without the support and guidance of my committee members, Dr. Leslie Gonzalez Rothi, Dr. Diane Kendall, and Dr. Lisa Edmonds. I feel fortunate to have had the opportunity to learn the research process from these independent women thinkers. I thank Dr. Leslie Gonzalez Rothi for her positive energy and infinite supply of new ideas throughout this project. I thank Dr. Diane Kendall for making me a part of her Aphasia Lab at the University of Florida and for continuing to include me as a lab member after her transition to the University of Washington. I also sincerely thank the members of the Aphasia Lab at the University of Washington, who through phone conferences (and one group picnic in Seattle) always embraced me as a member of the lab through their shared ideas and support. I am grateful to Dr. Lisa Edmonds for her help with this project and for involving me in the Gainesville Stroke Support Group. The amazing members of this group consistently motivated me to complete this investigation of the deficits that result from stroke. In addition, though not formally a committee member, I give the deepest thanks Dr. Anna Moore for providing her time and valuable input during this project.

The participants, both the stroke survivors who comprised our convenience sample and those who served as normal controls deserve the utmost appreciation for their time and dedication to stroke research. The continued volunteer participation of these individuals cannot be undervalued.

I extend my gratitude to my classmates and friends, particularly Christina del Toro and Lauren Bislick for their unwavering confidence in my ability to successfully complete this project and for sharing their own experiences with me. My parents, who have always held a level of confidence in me that seemed beyond my own capabilities, have provided me with an immeasurable amount of motivation during this process. Finally I thank my husband for his help, encouragement, and for his true appreciation of the value of this work.

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of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Arts

AN INVENTORY OF COGNITIVE DEFICITS IN CHRONIC STROKE SURVIVORS

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May 2010

Chair: Leslie J. Gonzalez Rothi
Major: Communication Sciences and Disorders

Stroke is a common and enduring, health condition; the consequences of which result in serious, long-term disability (Stineman et al., 1997). Cognitive deficits are said to be the most influential correlates of long-term dependency (Sundet, Finset, & Reinvang, 1988; Denti, Agosti, Franceschini, 2008; Heruti RJ, Lusky A, Dankner R, Ring H, Dolgopiat M, Barell V, Levenkrohn S, Adunsky A., 2002; Granger, Cotter, Hamilton, & Fiedler, 1993; Schuman, Beattie, Steed, Merry, & Kraus, 1981; Cifu & Lorish, 1994; Diamond, Felsenthal, Macciocchi, Butler, & Lally-Cassady, 1996; Paolucci, Antonucci, Gialloreti, Traballesi, Lubich, & Pratesi et al., 1996; Hajek, Gagnon, &Ruderman, 1997). However, there exists little information regarding which areas of cognitive impairment are likely to be present in the chronic stroke survivor. Thus our research question was: In a convenience sample of 384 stroke survivors, what are the persistent cognitive impairments? The performances of this convenience sample of stroke survivors on multiple standardized and non standardized tests were analyzed and categorized by area of cognitive impairment. Examination of this inventory revealed that executive function was the more prevalent area of cognitive impairment

followed by memory, alexia, attention, psychomotor function, aprosodia, agraphia, and aphasia.

CHAPTER 1
INTRODUCTION

Stroke is a common and enduring, health condition; the consequences of which result in serious, long-term disability (Stineman et al., 1997). Impairments associated with stroke involve sensory/motor, affective, and/or cognitive systems in combinations unique to each survivor. While sensory/motor deficits or affective alterations may be more readily apparent to the observer, “cognitive” deficits are said to be the most influential correlates of long-term dependency (Sundet, Finset, & Reinvang, 1988; Denti, Agosti, Franceschini, 2008; Heruti RJ, Lusky A, Dankner R, Ring H, Dolgopiat M, Barell V, Levenkrohn S, Adunsky A., 2002; Granger, Cotter, Hamilton, & Fiedler, 1993; Schuman, Beattie, Steed, Merry, & Kraus, 1981; Cifu & Lorish, 1994; Diamond, Felsenthal, Macciocchi, Butler, & Lally-Cassady, 1996; Paolucci, Antonucci, Gialloreti, Traballesi, Lubich, & Pratesi et al., 1996; Hajek, Gagnon, &Ruderman, 1997). Much of what is reported about the influence of cognitive dysfunction on stroke outcome (Sundet, Finset, & Reinvang, 1988; Denti, Agosti, Franceschini, 2008; Heruti RJ, Lusky A, Dankner R, Ring H, Dolgopiat M, Barell V, Levenkrohn S, Adunsky A., 2002, Diamond, Felsenthal, Macciocchi, Butler, & Lally-Cassady, 1996) is defined by a general index of “cognitive function,” such as the Mini Mental Status Exam (MMSE; Folstein et al., 1975) or the Functional Independence Measure (FIM; Guide for the Uniform Data Set for Medical Rehabilitation, 1996). General index measures of cognitive function utilize a single score summing performances on multiple tasks tapping unique combinations of cognitive functions. While these assessments evaluate cognition in a global sense, e.g., the MMSE taps orientation, registration, attention and calculation, recall, and language, general index tests do not yield individual scores for the discrete domains of cognition, but rather one score indicative of mild, moderate, or severe cognitive impairment. However, cognition is a superordinate term denoting mental thought which is underwritten by multiple, distinctive and dissociable processes, which some studies show to have differential and possibly unique impacts on functional outcomes. For example, Sundet, Finset, and Reinvang (1988) reported that the presence of apraxia was most highly correlated with increased levels of dependency as reported by caregivers, when compared with aphasia, nonverbal intelligence, memory and learning capacity, visual neglect, and emotional reactions. Jehkonen et al. (2000) found visual neglect to be the best predictor of functional outcome when compared with other factors including hemianopia, age, cognitive deficits (as measured by two memory tasks), and hemiparesis. While these studies are valuable in their contributions to the knowledge that discrete cognitive domains may have differential impacts on functional outcomes, they evaluate the impacts of few select cognitive domains, and only the Sundet, Finset, and Reinvang (1988) study assessed more than two domains of cognition at a time and only in 145 total subjects.

In summary, cognition is considered a potent indicator of outcome, but the method of measurement in most of the literature has been a global index, and cognition is a superordinate term for multiple discrete systems. These discrete systems may have differential impacts (Unsal-Delialioglu, 2008; Sundet, Finset, and Reinvang, 1988; Jehkonen et al., 2000), but only one study reported sampling more than two cognitive domains at a time and the one that sampled more was based upon only 145 subjects. To begin to assess impact at long term follow-up, this project was designed to assess what cognitive disorders were present greater than 6 months post onset. Additionally, the purpose of this study is to examine the proportionate frequency with which specific cognitive and linguistic deficits occur in individuals living with the chronic effects of left and right hemisphere strokes by reporting the presence of chronic problems in 7 commonly assessed cognitive systems including memory, psychomotor function, attention, executive function, aphasia, agraphia/alexia, and aprosodia in a convenience sample of self selected stroke survivors. Our research question was: In a convenience sample of 384 stroke survivors, what are the persistent cognitive impairments?

CHAPTER 2
METHODS

The methods for this study included a retrospective analysis of performance scores on a set of screening measures (standard and non-standard) chosen to briefly assess whether a stroke survivor did or did not have an impairment in a subset of cognitive domains. Because these screening measures included non-standard screening tests, the methods for this study also included the collection of normative data on all non-standardized screening tests.

The cognitive domains selected for evaluation in this study are those which are frequently found to be impaired in stroke survivors, are often the subject of research and rehabilitation efforts, and areas in which if a deficit is present, can disqualify patients from receiving physical rehabilitation services. Therefore, the five cognitive domains selected for evaluation in this study include language, executive function, attention, memory, and psychomotor function. Additionally, because the data was readily available, we elected to evaluate for the presence of alexia/agraphia and aprosodia and have included these domains in our inventory.

Retrospective Data Collection

Database Description

Archival data were used for this study from the VA (Veterans Affairs) Brain Rehabilitation Research Center (BRRC) in Gainesville, Florida. Individuals who had suffered a left and/or right hemisphere cerebral vascular accident (CVA) self-referred to be screened at the BRRC to determine eligibility for potential neurorehabilitation research studies. During the comprehensive evaluation, a licensed speech-language pathologist and a neuropsychologist administered a battery of standardized tests including the Western Aphasia Battery (WAB; Kertesz, 1982), the Wide Range Assessment of Memory and Learning, 3rd Edition (WRAML-3; Adams & Sheslow, 1990), the Brief Visuospatial Memory Test-Revised (BVMT-R; Benedict, 1997), the Wechsler Memory Scale, 3rd Edition (WMS-III; Wechsler, 1997), the Trail Making Test (Reitan & Wolfson,1985), the Rey Osterrieth Complex Figure (REY-O; Stern et al., 1999), the Stroop Color Word Test (Stroop, 1935), and the maze portion of the Weschler Intelligence Scale for Children, 3rd Edition (WISC-3; Wechsler, 1991). In addition to this standardized testing, multiple non-standardized tests were conducted which contributed to the screen. These include tests of letter cancellation, right/left discrimination, line bisection, motor impersistence, identification of word similarities, selections from the Florida Affect Battery (Bowers, Blonder, & Heilman, 1991), selections from Ravens Progressive Matrices (Raven, 1976), and tests of agraphia, alexia, and aprosodia. All data from standardized and non-standardized assessments were entered into an Access Database.

Procedures for Data Extraction and Participants

For the current study, data were extracted from the database of information collected under IRB # 457-1999 by a subject coordinator using the following inclusion criteria: CVA at least 6 months prior to examination. Data from individuals were excluded if there were bilateral strokes or progressive neurologic disease. The participant information was then de-identified by the subject coordinator and given to the researchers for analysis.

Analyses of Archival Data

Areas of cognitive impairment and test selection

For the cognitive domains, including memory, psychomotor, attention, and executive function, a neuropsychologist selected specific tests within each domain to determine impairment in that domain. Similarly, for the linguistic domains of aphasia, agraphia, alexia, and aprosodia, a speech-language pathologist selected specific tests within each domain to determine impairment. Table A-1 lists the screens in each domain used to determine impairment.

Analysis of performance on standardized tests

Impairment on the standardized assessments including the Western Aphasia Battery (WAB; Kertesz, 1982), the Wide Range Assessment of Memory and Learning, 3rd Edition (WRAML-3; Adams & Sheslow, 1990), the Brief Visuospatial Memory Test-Revised (BVMT-R; Benedict, 1997), the Wechsler Memory Scale, 3rd Edition (WMS-III; Wechsler, 1997), the Trail Making Test (Reitan & Wolfson,1985), the Rey Osterrieth Complex Figure (REY-O; Stern et al., 1999), the Stroop Color Word Test (Stroop, 1935), and the maze portion of the Weschler Intelligence Scale for Children, 3rd Edition (WISC-3; Wechsler, 1991), were classified based on the normative samples established for the individual standardized tests.

Analysis of performance on non-standardized tests

All non-standardized tests given to participants with stroke during screening were given to 15 normal controls during this project in order to establish normative values. Ranges of normative control scores were calculated for each non-standardized test. Individuals with stroke were classified as impaired on a non-standardized assessment if the score was outside of the range of normal control scores that were established within this project.

Development of percentage/domain impairment

Because the purpose of this study is to investigate the proportionate frequency with which specific cognitive and linguistic deficits occur in individuals living with the chronic effects of left and right hemisphere strokes, the presence of impairment in 7 commonly assessed cognitive systems including memory, psychomotor function, attention, executive function, aphasia, agraphia/alexia, and aprosodia was evaluated among a convenience sample of self selected stroke survivors. This was accomplished by first establishing normative ranges for non-standardized tests. Next, an analysis of the scores from the archival data of individuals with stroke on the standardized and non-standardized tests within each cognitive domain was conducted for each individual, revealing the specific tests on which each individual scored outside of the normal range. A score outside of the normal range on any test included in a particular domain (see Table A-1) indicated impairment in that cognitive domain. The number of individuals impaired in each domain was then calculated. Based on that data, the percentage of individuals impaired in each domain was determined.

Normal Controls

Purpose for Collection of Normative Data

Normal control data were collected to establish normative values upon which to compare performance from individuals with stroke on non-standardized tasks.

Normal Participants

Normal participants were selected to match the demographics of the convenience sample for age and education levels. Normal controls consisted of 15 right-handed, monolingual English speaking individuals with no history by self-report of stroke, other neurological disease, or speech/language disorder. This study was approved by the University of Florida Institutional Review Board (IRB # 2009-U-0244) and all participants gave their consent.

Procedures for Collecting Normative Data

Test administration

Normal Control participants were asked to sit in a comfortable location with a Speech Language Pathology graduate student and complete pen and paper or verbal response tasks. All verbal responses were recorded using a Marantz PMD671 recorder. Cognitive domains tapped in this assessment included memory, psychomotor, attention, executive function, aphasia, alexia, agraphia, and aprosodia.

Materials

Tasks consisted of the non-standardized versions of commonly used cognition sampling tasks including letter cancellation, right/left discrimination, line bisection, motor impersistence, identification of word similarities, selections from the Florida Affect Battery (Bowers, Blonder, & Heilman, 1991), selections from Ravens Progressive Matrices (Raven, 1976), and tests of agraphia, alexia, and aprosodia. Detailed descriptions of non standardized tests can be found in Appendix C.

Analysis of Normative Data

Analysis of normative data was conducted by a speech-language pathology graduate student. All responses on all tests were scored online. Detailed descriptions of non-standardized tests and scoring processes are listed in Appendix C. Verbal responses were recorded and written responses were maintained for the purpose of conducting intra-rater reliability. Intra-reliability was later conducted on 100% of participant responses. Participant responses for each test were then analyzed and normative ranges for performance on each test were established.

CHAPTER 3
RESULTS

Participants with Stroke

Demographics of Participants with Stroke

The data extraction resulted in a dataset that included a total of 384 participants. Two hundred fifty men and 134 women, with an average age of 62.84 years (min 50.74, max 74.94) served as participants. Relevant demographic information of stroke participants is listed in the results section in Table A-2.

Test Performance of Stroke Survivors

The average and standard deviations for the performance of stroke survivors on individual standardized and non-standardized tests are listed in Table A-3. Tests are listed under the domain for which they determine impairment. Additionally, because some aspects of cognitive deficits are lateralized, test performance was analyzed separately in individuals with right hemisphere lesions versus left hemisphere lesions. This analysis revealed that there were differences in the average scores between groups on subtests of language, memory, executive function, and attention. See Table A-4 for test performance of individuals with right hemisphere lesions and Table A-5 for test performance of individuals with left hemisphere lesions.

Stroke Participant Data Analysis

The evaluation of the performance of stroke survivors on all testing revealed a proportionate frequency among all commonly assessed cognitive domains in which a person with stroke is likely to be impaired. See Table A-6 for the percentage of individuals impaired in each cognitive domain.

Normal Controls

Purpose for Collection of Normative Data

Normative data were collected in order to establish a normative range of scores against which to compare the performance of stroke survivors on all non-standardized tests.

Demographics of Normative Controls

Eleven women and four men, with an average age of 61.3 years (min 49, max 81 years) served as participants. Table A-7 lists the relevant normal control participant demographic information.

Normal Control Data Analysis

Normative data on non-standardized tests revealed a range of normative scores for each test. Scores of stroke survivors outside these normative ranges were used to indicate the presence of impairment on non-standardized tests. The results of normative data which were used to classify stroke survivors as impaired or unimpaired on all non-standardized tests are listed in Table A-8.

CHAPTER 4
DISCUSSION

The purpose of this study was to rank the proportionate frequency with which cognitive and linguistic deficits occur in a convenience sample of self-selected stroke survivors living with the chronic effects of left and right hemisphere strokes. To address this aim we asked the following research question: of a subset of commonly assessed cognitive systems, what are the persistent cognitive impairments in stroke survivors? The five commonly assessed cognitive systems examined in this study were memory, psychomotor function, attention, executive function, and language. Because the data were readily available, we also evaluated for the presence of agraphia/alexia and aprosodia.

The results of data analysis on the performance of stroke survivors on multiple standardized and non standardized tests which were categorized by area of cognitive impairment revealed that executive function is the most prevalent area of cognitive impairment followed by memory, alexia, attention, psychomotor function, aprosodia, agraphia, and finally aphasia. That the area of executive function was the area most frequently impaired was not surprising. The neuroanatomical structures which are involved in the many aspects which make up the construct of executive function are widely distributed (Collette, 2006), leaving them vulnerable to injury from stroke. It is discordant then that as the most frequent area of impairment in our convenience sample, executive function should be the subject of such little research and so rarely the focus of rehabilitation efforts.

In addition to impairment in the area of executive function, the prevalence with which the remaining areas of cognitive deficit present in our convenience sample has significant implications for rehabilitation of the stroke population. Memory for example, was impaired in 70% of our sample and the second most frequently impaired area, plays a major role in rehabilitation, and is perhaps the most important component of "ability to learn." The high prevalence of alexia in our sample suggests that this area of deficit is one which deserves considerable attention from therapists, even in individuals who do may not be classified as "aphasic" on the Western Aphasia Battery (WAB; Kertesz, 1982). Attention and psychomotor function, which were the fourth and fifth most common areas of impairment, are also important factors for all areas of rehabilitation. Aphasia, which ranked as the least common area of impairment in our convenience sample, is the subject of extensive research and, if present, is frequently the focus of rehabilitation efforts. The range of prevalence for all cognitive domains in our convenience sample was 47-83%, so it must be acknowledged that there is a high possibility that impairment in one or multiple domains will be present post stroke.

Because the overall prevalence of cognitive deficits in our population was so high, and because some aspects of cognitive deficits are known to be lateralized, the test performances of stroke survivors were analyzed separately in individuals with right hemisphere lesions versus left hemisphere lesions. As expected, the individuals with left hemisphere lesions had a lower average score on the Western Aphasia Battery (WAB; Kertesz, 1982) than did the group with right hemisphere lesions and were more likely to have lower scores on tests of alexia and agraphia. The group of individuals with left hemisphere lesions also had lower scores on certain subtests of memory, attention, and executive function, which may be attributed to the fact that performance on many cognitive tests is dependent on in-tact language skills. Performance on screening tests by lesion site is further described in Tables A-4 and A-5.

The implications of the results of our study depend on how well our convenience sample of stroke survivors represents the general population. First, the sample used in this study had a greater number of individuals with left hemisphere lesions than individuals with right hemisphere lesions. While it has been found that left hemisphere incidents occur with greater frequency in the inpatient stroke population (Foerch, 2005), our ratio of 67% of individuals with left hemisphere strokes and 33% with right hemisphere strokes is not exactly representative of the proportion as it occurs in the inpatient stroke population, which was found to be 56% left hemisphere and 44% right hemisphere (Foerch, 2005). Second, the average age at onset of stroke for our convenience sample of stroke survivors was 58.87 years which is lower in age than the average age of onset of 70 years men, 74 years women (Lai et al., 1994). See scatter-plot of participant ages at stroke onset (Appendix B Figure B-1). Another consideration is that the participants in our convenience sample may have higher levels of motivation than the average stroke survivor due to the fact that they were self-referred to the Brain Rehabilitation Research Center. The majority of our participants may also have benefited from motivated caregivers, as their caregivers were often responsible for transportation of the stroke survivor to the BRRC for screening. Additionally, while the normative sample was matched for age and education level, matching of gender could not be accomplished. The convenience sample of stroke survivors has nearly two times as many men as women, while the majority of the normative subjects were women. How effectively the scores of the normative sample, consisting largely of women, were able to determine impairment in the convenience sample of stroke survivors, consisting largely of men, is unknown, but it seems unlikely to have caused a significant difference in our results.

Another aspect of this study which determines how effectively the results can be translated to the general population is the level to which the tests used in this study were good indicators of impairment in a given cognitive system. Tests were not necessarily equivalent in how well they measured the area of impairment they claimed to target. For example, we found the presence of Aphasia in our population to be disproportionate for what would be expected given our population. While 259 individuals had left hemisphere lesions and 129 individuals had right hemisphere lesions, the proportionate frequency of aphasia was only 46%. It is possible that the test used to determine the presence of aphasia, the Western Aphasia Battery (WAB; Kertesz, 1982) was not sensitive enough to detect aphasia in all cases. Alternatively, executive function, which was found to be impaired in 83% of our convenience sample, was determined by impairment in any one test which tapped the any aspect of executive function. We must then acknowledge the possibility that the tests used to measure impairment in each cognitive domain varied in their levels of sensitivity and specificity.

Given the methodological issues associated with the use of a convenience sample, this study gives valuable information regarding the high frequency with which chronic cognitive deficits occur among stroke survivors. Still another subject the results of this study provokes is that these cognitive deficits did not all occur with the same frequency. While cognitive domains are known to overlap, e.g., the category of executive function shares features with the cognitive category of attention, our results indicate that specific areas of cognitive impairment are distinct and dissociable from one another. Given that information, it does not seem beneficial to patients or researchers to utilize general index measures of cognition when determining cognitive impairment because so little information about the nature of cognitive deficits can be gathered from these types of tests.

While the impact of these areas of impairment has yet to be determined, we do know that impairments in these cognitive domains are prevalent, distinct in the frequency with which they occur, and that these impairments are lasting. At the clinical level, it is hoped that these results will help to transform the belief from the view that "cognition" is one body into the view that cognition is made up of multiple components and that impairments in these areas can be addressed as to their differential impacts. This study brings to light implications for future research regarding functional impacts of impairments in these cognitive domains using outcome measures such as level of independence, quality of life, and caregiver depression.

APPENDIX A
TABLES

Table A-1. Domains with tests used to classify impairment

Domain	Tests
Memory	WRAML story memory (immediate and delay), WRAML story recognition, BVMT-R (total recall, delayed recall, percent retained), WMS III word list (recall, recognition, delay)
Psychomotor	Letter Cancellation*, Trails A time score, WISC-3 maze total time
Attention	Line Bisection*, WMS III digit span total, Trails A errors
Executive Function	WMS III spatial span total, Florida Affect Battery, Stroop color-word total score, Motor impersistence time*, Similarities total score*, Trails B time, Trails B errors, Rey-O figure total score, Raven's Matrices total score*, WISC-3 maze time, WISC-3 maze errors
Aphasia	WAB (score of 93.7 or below)
Agraphia	Non-standardized tasks including writing name and address, a sentence about the weather, words to dictation, numbers, numbers to dictation*
Alexia	Non-standardized tasks including real-word reading aloud, non-word reading aloud, psuedohomophone reading aloud, paragraph comprehension, and phoneme perception*
Aprosodia	Non-standardized tasks of expressive and receptive prosody*

*All non-standardized tasks are described in full in Appendix C.

Standardized Tests: Western Aphasia Battery (WAB; Kertesz, 1982), the Wide Range Assessment of Memory and Learning, 3rd Edition (WRAML-3; Adams & Sheslow, 1990), the Brief Visuospatial Memory Test-Revised (BVMT-R; Benedict, 1997), the Wechsler Memory Scale, 3rd Edition (WMS-III; Wechsler, 1997), the Trail Making Test (Reitan & Wolfson,1985), the Rey Osterrieth Complex Figure (REY-O; Stern et al., 1999), the Stroop Color Word Test (Stroop, 1935), the maze portion of the Weschler Intelligence Scale for Children, 3rd Edition (WISC-3; Wechsler, 1991), selections from the Florida Affect Battery (Bowers, Blonder, & Heilman, 1991), selections from Ravens Progressive Matrices (Raven, 1976).
Non-Standardized Tests: Multiple non-standardized tests were also utilized including tests of letter cancellation, right/left discrimination, line bisection, motor impersistence, identification of word similarities, and non standardized tests of agraphia, alexia, and aprosodia.

Table A-2. Demographics of individuals with stroke

Total number of participants	384
Male	250
Female	134
Right CVA	125
Left CVA	259
English as First Language	146
Other Language as First Language	238
English as Only Language	112
Speaks More Than One Language	272
Right Handed	336
Left Handed	38
Ambidextrous	10
	Averages (Std. Dev)
Age at Stroke Onset	58.87 (+/- 13.20)
Months Post Onset	43.20 (+/- 52.20)
Age at time of screen	62.84 (+/- 12.10)
Years of Education	13.71 (+/- 4.23)

Table A-3. Performance of stroke survivors on standardized and non-standardized tests listed by area of cognitive impairment

Executive Function	Average	Standard Dev.	Max	Min	Range
Spatial Span total SS score	8.5	3.6	21.0	1.0	20.0
FI affect discrimination raw	5.9	1.4	8.0	0.0	8.0
Stroop color/word total score percentile	17.2	32.9	324.0	1.0	323.0
Motor impersistence total time raw	18.7	5.9	70.0	0.0	70.0
Similarities total score raw	4.4	2.3	9.0	0.0	9.0
Trails B Time T score	35.7	13.5	125.0	2.0	123.0
Trail B errors raw	1.8	2.0	11.0	0.0	11.0
Rey-O Figure total score standardized		scored as impaired/unimpaired			
Ravens Matrices total score raw	3.1	1.4	6.0	0.0	6.0
Maze total time raw (sec)	136.0	72.7	403.0	0.0	403.0
Maze Total errors raw	2.5	7.1	95.0	0.0	95.0
Memory					
WRAML immediate total raw	7.7	7.0	81.0	0.0	81.0
WRAML delay total raw	6.6	5.3	21.0	0.0	21.0
WRAML recognition total raw	10.1	6.2	86.0	0.0	86.0
BVMT-R Total Recall T score	36.8	12.0	68.0	1.0	67.0
BVMT-R delayed recall total T score	38.0	13.8	67.0	0.0	67.0
BVMT-R % retained percentile	10.6	5.0	16.0	1.0	15.0
WMS-III word list A recall total SS score	6.4	3.0	16.0	1.0	15.0
WMS-III word list recognition total SS score	9.0	2.5	14.0	3.0	11.0
WMS III word list long delay standardized	6.5	2.0	17.0	3.0	14.0
Alexia					
Real word reading aloud	6.8	3.3	10.0	0.0	10.0
Nonword reading aloud	5.0	3.4	10.0	0.0	10.0
Pseudo-homophone reading aloud	2.7	1.7	5.0	0.0	5.0
Paragraph comprehension	2.6	1.4	4.0	0.0	4.0
Phoneme perception	3.8	1.3	5.0	0.0	5.0
Attention					
WMS III standardized %tile	44.3	28.7	78.0	1.0	77.0
Letter Cancellation in errors raw	0.5	1.3	10.0	0.0	10.0
Spatial Span total SS score	8.5	3.6	21.0	1.0	20.0
Right Left orientation total score raw	3.1	1.2	4.0	0.0	4.0
Line bisection trial 1% deviation raw	3.8	10.1	117.0	0.0	117.0
line bisection trial 2% deviation raw	4.9	44.9	710.0	0.0	710.0
Line Bisection trial 3% deviation raw	1.9	1.8	10.0	0.0	10.0
Digit span total ss score	7.9	4.8	62.0	1.0	61.0
Trails A errors raw	0.6	1.5	15.0	0.0	15.0

Table A-3. Continued

Psychomotor					
Letter cancellation in sec raw	35.1	21.9	190.0	9.0	181.0
Trails A Time T score	35.3	12.9	92.0	1.0	91.0
Maze total time	135.7	72.4	403.0	0.0	403.0
Aprosodia					
Prosody expressive	5.7	3.4	10.0	0.0	10.0
Prosody receptive	6.6	2.6	10.0	0.0	10.0
Agraphia					
Writing name and address	1.8	0.5	2.0	0.0	2.0
Real words to dictation	4.6	3.2	10.0	0.0	10.0
Sentence writing grammar	0.7	0.5	1.0	0.0	1.0
Number writing 0-10	9.3	2.2	10.0	0.0	10.0
Number writing to dictation	2.6	0.8	3.0	0.0	3.0
Aphasia					
Western Aphasia Battery AQ	78.4	26.3	100.0	0.9	99.1

Table A-4. Performance of right CVA survivors on standardized and non-standardized tests listed by area of cognitive impairment

Executive Function	Average	Standard Dev.	Max	Min	Range
Spatial Span total SS score	8.7	3.8	21.0	1.0	20.0
FI affect discrimination raw	6.2	1.2	8.0	3.0	5.0
Stroop color/word total score percentile	28.5	46.8	324.0	1.0	323.0
Motor impersistence total time raw	17.6	5.2	20.0	2.0	18.0
Similarities total score raw	5.4	1.9	9.0	1.0	8.0
Trails B Time T score	38.2	13.2	71.0	4.0	67.0
Trail B errors raw	1.4	1.8	10.0	0.0	10.0
Rey-O Figure total score standardized		Scored as impaired/unimpaired			
Ravens Matrices total score raw	3.2	1.4	6.0	0.0	6.0
Maze total time raw (sec)	138.1	81.9	403.0	0.0	403.0
Maze Total errors raw	3.5	10.7	95.0	0.0	95.0
Memory					
WRAML immediate total raw	11.6	8.8	81.0	1.0	80.0
WRAML delay total raw	9.8	4.8	21.0	0.0	21.0
WRAML recognition total raw	10.6	2.3	15.0	2.0	13.0
BVMT-R Total Recall T score	39.0	11.0	63.0	20.0	43.0
BVMT-R delayed recall total T score	41.4	13.5	67.0	0.0	67.0
BVMT-R % retained percentile	10.0	5.5	16.0	1.0	15.0
WMS-III word list A recall total SS score	7.6	2.5	16.0	2.0	14.0
WMS-III word list recognition total SS score	9.8	1.7	14.0	3.0	11.0
WMS III word list long delay standardized	6.7	2.1	16.0	3.0	13.0
Alexia					
Real word reading aloud	7.7	2.5	10.0	4.0	6.0
Nonword reading aloud	6.5	2.8	10.0	0.0	10.0
Pseudo-homophone reading aloud	3.5	1.4	5.0	0.0	5.0
Paragraph comprehension	3.5	0.9	4.0	0.0	4.0
Phoneme perception	4.2	0.9	5.0	2.0	3.0
Attention					
WMS III standardized %tile	55.7	24.1	78.0	6.0	72.0
Letter Cancellation in errors raw	0.2	0.5	2.0	0.0	2.0
Spatial Span total SS score	8.6	3.9	21.0	1.0	20.0
Right Left orientation total score raw	3.6	0.8	4.0	1.0	3.0
Line bisection trial 1% deviation raw	5.2	12.6	103.0	0.0	103.0
line bisection trial 2% deviation raw	2.1	2.0	9.1	0.0	9.1
Line Bisection trial 3% deviation raw	2.0	1.8	7.8	0.0	7.8
Digit span total ss score	9.4	2.6	17.0	5.0	12.0
Trails A errors raw	0.4	0.9	6.0	0.0	6.0

Table A-4. Continued

Psychomotor	Average	Standard Dev.	Max	Min	Range
Letter cancellation in sec raw	34.4	24.2	190.0	10.0	180.0
Trails A Time T score	35.1	13.6	69.0	1.0	68.0
Maze total time	138.1	81.9	403.0	0.0	403.0
Aprosodia					
Prosody expressive	5.5	3.3	10.0	0.0	10.0
Prosody receptive	6.7	2.5	10.0	0.0	10.0
Agraphia					
Writing name and address	1.8	0.5	2.0	0.0	2.0
Real words to dictation	4.6	3.2	10.0	0.0	10.0
Sentence writing grammar	0.8	0.4	1.0	0.0	1.0
Sentence writing spelling errors	0.2	0.4	1.0	0.0	1.0
Sentence writing legibility	1.0	0.2	1.0	0.0	1.0
Sentence writing content	1.0	0.2	1.0	0.0	1.0
Number writing 0-10	9.3	2.2	10.0	0.0	10.0
Number writing to dictation	2.6	0.8	3.0	0.0	3.0
Aphasia					
Western Aphasia Battery AQ	94.9	11.7	100.0	0.9	99.1

Table A-5. Performance of left CVA survivors on standardized and non-standardized tests listed by area of cognitive impairment

Executive Function	Average	Standard Dev.	Max	Min	Range
Spatial Span total SS score	8.3	3.2	15.0	2.0	13.0
Fl affect discrimination raw	5.7	1.6	8.0	0.0	8.0
Stroop color/word total score percentile	13.2	19.5	74.0	1.0	73.0
Motor impersistence total time raw	19.5	7.3	70.0	0.0	70.0
Similarities total score raw	3.9	2.5	9.0	0.0	9.0
Trails B Time T score	34.7	15.9	125.0	2.0	123.0
Trail B errors raw	2.0	1.9	8.0	0.0	8.0
Rey-O Figure total score standardized		Scored as impaired/unimpaired			
Ravens Matrices total score raw	3.1	1.5	6.0	0.0	6.0
Maze total time raw (sec)	139.4	74.3	400.0	49.0	351.0
Maze Total errors raw	2.6	6.6	61.0	0.0	61.0
Memory					
WRAML immediate total raw	6.1	5.3	20.0	0.0	20.0
WRAML delay total raw	5.1	4.8	20.0	0.0	20.0
WRAML recognition total raw	10.5	9.8	86.0	0.0	86.0
BVMT-R Total Recall T score	36.5	13.3	68.0	1.0	67.0
BVMT-R delayed recall total T score	35.6	14.5	65.0	0.0	65.0
BVMT-R % retained percentile	11.2	5.0	16.0	1.0	15.0
WMS-III word list A recall total SS score	5.6	2.9	8.0	2.0	6.0
WMS-III word list recognition total SS score	8.5	2.9	10.0	3.0	7.0
WMS III word list long delay standardized	5.9	0.4	6.0	3.0	3.0
Alexia					
Real word reading aloud	4.8	3.2	10.0	0.0	10.0
Nonword reading aloud	3.3	3.1	10.0	0.0	10.0
Pseudo-homophone reading aloud	2.1	1.7	5.0	0.0	5.0
Paragraph comprehension	2.6	1.4	4.0	0.0	4.0
Phoneme perception	3.6	1.4	5.0	0.0	5.0
Attention					
WMS III standardized %tile	41.5	28.7	75.0	3.0	72.0
Letter Cancellation in errors raw	0.8	1.7	10.0	0.0	10.0
Spatial Span total SS score	8.2	3.4	15.0	1.0	14.0
Right Left orientation total score raw	2.8	1.2	4.0	0.0	4.0
Line bisection trial 1% deviation raw	4.0	12.0	117.0	0.0	117.0
line bisection trial 2% deviation raw	8.4	66.6	710.0	0.0	710.0
Line Bisection trial 3% deviation raw	1.9	1.8	10.0	0.0	10.0

Table A-5. Continued

Digit span total ss score	7.7	7.0	62.0	1.0	61.0
Trails A errors raw	0.8	1.8	15.0	0.0	15.0
Psychomotor	Average	Standard Dev.	Max	Min	Range
Letter cancellation in sec raw	35.0	22.4	130.0	10.0	120.0
Trails A Time T score	34.7	13.4	92.0	4.0	88.0
Maze total time	138.4	73.4	400.0	49.0	351.0
Aprosodia					
Prosody expressive	5.5	3.5	10.0	0.0	10.0
Prosody receptive	6.7	2.6	10.0	1.0	9.0
Agraphia					
Writing name and address	1.7	0.6	2.0	0.0	2.0
Real words to dictation	3.0	2.8	10.0	0.0	10.0
Sentence writing grammar	0.6	0.5	1.0	0.0	1.0
Sentence writing spelling errors	0.5	0.5	1.0	0.0	1.0
Sentence writing legibility	0.7	0.5	1.0	0.0	1.0
Sentence writing content	0.7	0.5	1.0	0.0	1.0
Number writing 0-10	8.8	2.8	10.0	0.0	10.0
Number writing to dictation	2.4	1.0	3.0	0.0	3.0
Aphasia					
Western Aphasia Battery AQ	71.6	27.3	100.0	5.4	94.6

Table A-6. Percentage stroke survivors of impaired in cognitive domains (N=384)

Executive Function	83%
Memory	70%
Alexia	67%
Attention	64%
Psychomotor	63%
Aprosodia	60%
Agraphia	57%
Aphasia	47%

Table A-7. Demographics of normal controls

Total number of participants	15
Male	4
Female	11
	Averages (Std. Dev)
Age at time of testing	61.3 (+/- 9.6)
Years of education	14.8 (+/- 2.9)

Table A-8. Normal control scores on non-standardized tests

Test/Task	Average	Standard Dev	Max	Min	Range
Letter Cancellation Time	10.60	1.30	13	9.00	4.00
Letter Cancellation Errors	0	0	0	0	0
Right/Left Orientation	4.00	0.00	4	4.00	0.00
Line Bisection % deviation	0%	0	0	0	0
Motor Impersistence	20.00	0.00	20	20.00	0.00
Similarities	6.40	1.80	9	4.00	5.00
Facial Affect Battery	7.47	0.74	8	6.00	2.00
Raven's Matrices	4.60	0.63	5	3.00	2.00
Agraphia: writing name and address	3.00	0.00	3	3.00	0.00
Agraphia: real words to dictation	9.60	0.83	10	7.00	3.00
Agraphia: sentence about weather	3.00	0.00	3	3.00	0.00
Agraphia: number writing	10.00	0.00	10	10.00	0.00
Agraphia: numbers to dictation	3.00	0.00	3	3.00	0.00
Alexia: real word reading	10.00	0.00	10	10.00	0.00
Alexia: non-word reading	9.47	0.74	10	8.00	2.00
Alexia: pseudohomophone reading	9.47	0.74	10	8.00	2.00
Alexia: paragraph comprehension	4.00	0.00	4	4.00	0.00
Alexia: phoneme perception	4.93	0.26	5	4.00	1.00
Aprosodia: expressive prosody	9.93	0.26	10	9.00	1.00
Aprosodia: receptive prosody	9.80	0.56	10	8.00	2.00

APPENDIX B
FIGURES

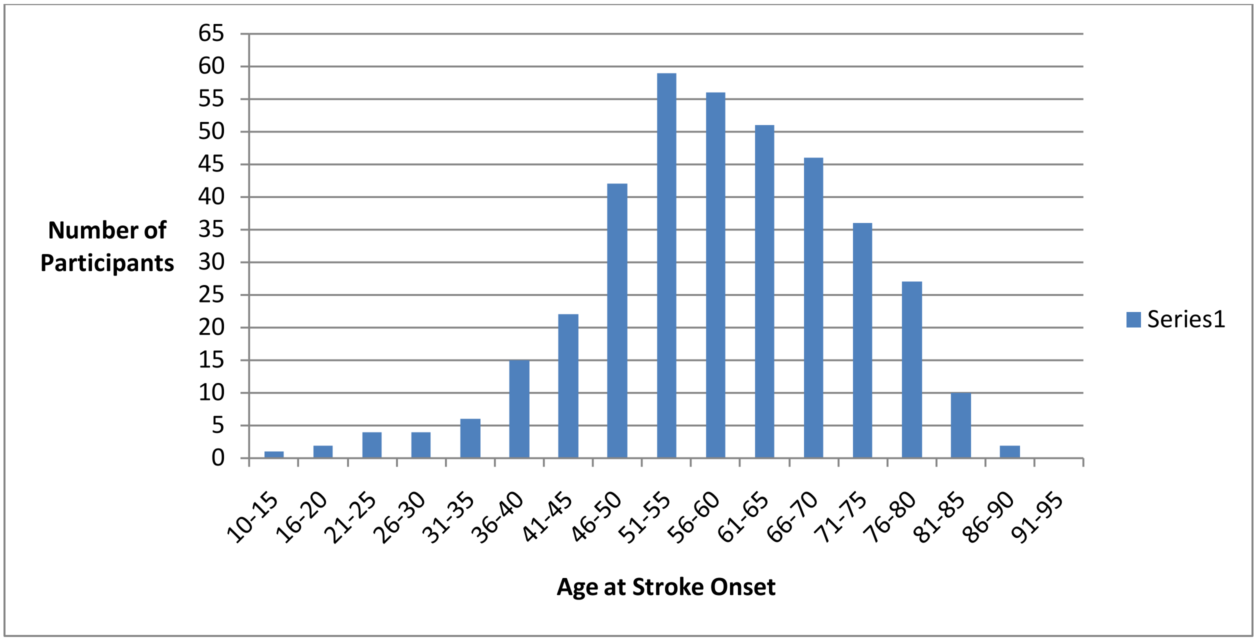

Figure B-1. Age of stroke survivors at stroke onset in years

APPENDIX C
DETAILED DESCRIPTIONS OF NON STANDARDIZED TESTS AND SCORING PROCESSES

Non standardized tests were administered to normal controls in order to test the specific cognitive domains targeted in the archival data. A letter cancellation task, which is within the psychomotor domain, was tested through a task which was conducted by giving the participant a sheet of paper with letters arranged in random order. The participant was then asked to cross out all letter "A"s while being timed. This task was scored by tallying the number of letter “A”s that were not crossed out as well as by the amount of time it took the participant to cross out all of the letter “A”s. A task of line bisection, which is within the domain of attention, was tested through was conducted by giving the patient a sheet of paper with a horizontal line and asking the patient to draw a vertical line in the middle of that line. The distance from the middle was then measured to yield a percent deviation from the true middle. The percent deviation across all normal participants was then used to calculate a normative range. Several tasks from the domain of executive function were conducted including a motor impersistence task, which was conducted by asking the patient to stick out his/her tongue and hold it for 20 seconds and which was scored as either correct (meaning that the participant held the tongue out for 20 seconds) or incorrect (meaning that the participant did not maintain the motor task for the full 20 seconds); a task of identification of similarities, which involved reading two words to a patient and asking him/her to reveal how the two could be related, for which a hierarchical scoring system is established based on the content of the patient’s answers; a task involving eight paired photos (#s 1, 2, 5, 6, 11, 12, 19, and 20) of faces expressing emotions were selected from the Florida Affect Battery (Bowers, Blonder, & Heilman, 1991), and the participant was asked to determine whether the faces were expressing similar or different emotions, which was scored as correct or incorrect; and specific patterns (#s 1, 6, 11, 16, 21, and 26) were selected from Ravens Progressive Matrices, (Raven, 1976) and the participant was asked to select the choice that best completed the pattern, which was also scored as either correct or incorrect. The test of agraphia included tasks such as writing name and address, writing words to dictation, writing a sentence about the weather, number writing, and writing numbers to dictation, all of which were scored as either correct or incorrect. The test of alexia included tasks of real-word reading aloud, non-word reading aloud, psuedohomophone reading aloud, paragraph comprehension, and phoneme perception, all of which were scored as either correct or incorrect. The test of aprosodia included tasks of expressive prosody, which were conducted by asking the participant to read aloud a sentence using the emotion (happy, sad, angry, neutral) pointed to by the tester, and tests of receptive prosody, which were conducted by asking the participant to point to the emotion (happy, sad, angry, neutral) that the tester was using while reading a sentence aloud. All prosody tasks were scored as either correct or incorrect.

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BIOGRAPHICAL SKETCH

Sally Ouimet Waters graduated cum laude from the University of Florida with a Bachelor of Arts in English in May 2005. Following her graduation she taught English as a Second Language to first and second grade students in central Florida. She entered the master's program in communication sciences and disorders at the University of Florida in August 2007 when she began working as a research assistant for Dr. Diane Kendall at the Brain Rehabilitation Research Center (BRRC) in Gainesville, FL. The master's program provided Sally with many opportunities for educational enrichment including the aforementioned research position, a poster presentation at the 2008 American Speech and Hearing Association (ASHA) convention, practicum placements at both Shands Speech and Hearing Center and Shands Rehabilitation Hospital, and her position as Administrative Coordinator of the Gainesville Stroke Support Group. Sally plans to complete her Clinical Fellowship Year in an inpatient or inpatient rehabilitation setting with a special interest in cognitive-linguistic deficits.