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In a Right State of Mind: An Analysis of Cognitive and Linguistic Function Following a Rare Case of Atypical Language Dominance in Aphasia

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In a Right State of Mind: 
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Dominance in Aphasia 

EMILY MANTON

Introduction

When thinking about the human brain, it is possible to compare its structural importance to that of a working machine. In order for meaningful function to be executed, the networks within the machine’s design must also be operative. Similarly, the brain’s capacity to create and execute meaningful communication is dependent upon the functionality of its individual units. Extensive research has found that in 97% of people worldwide, language is typically carried out by the left cerebral hemisphere. Data regarding lesions or injury to this side of the brain has been readily documented. However, for the 3% of individuals who demonstrate “atypical cerebral dominance,” or the execution of language from the right hemisphere of the brain, literature is scarce. Therefore, the purpose of this empirical prospective case study was to document the cognitive and language functions of a 59-year-old male who developed a type of language disorder (“aphasia”) following a right hemisphere stroke.

Clinical evidence supporting the phenomenon of cerebral dominance came as early as 1861, when physician Paul Broca localized the centers for language function to specific regions in the left cerebral hemisphere for the majority of the population. His argument for asymmetrical hemispheric function was established through studies on left hemisphere lesions in which correlations between the absence of motor speech and damage to this area were observed (Coppens, Papathanasiou, & Potagas, 2013). Broca’s discovery of the interrelationship between handedness and cerebral dominance has since prompted extensive studies on the brain’s ability to create and execute language and has led to the term “Broca’s aphasia” for certain forms of the disorder. Aphasia is generally defined as “an acquired language impairment occurring as the result of deficits in the language-dominant hemisphere of an individual” (Coppens, Papathanasiou, & Potagas, 2013).

According to Bhatnager (2013), and Coppens, Hungerford, Yamaguchi, & Yamadori (2002), the right hemisphere is specialized for language functions that include an individual’s ability to comprehend abstract notions, recognize visual and spatial concepts, and regulate and express emotion. It has been maintained that individuals who possess right hemisphere dominance demonstrate a pattern of neural organization different from their left hemisphere dominant counterparts. As a result, the manifestation of deficits following damage to these areas differ from those associated with typical left hemisphere lesions (Knecht et al., 2002). Aphasia resulting from right hemisphere damage is characterized by components including halting, ungrammatical speech, neglect of the left side, and visuospatial deficits (Bhatnager, 2013). For those who are left hemisphere dominant, damage would generate deficits in written and verbal abilities in addition to the auditory comprehension of language (Bhatnager, 2013).

As a result of Broca’s findings regarding neural function, studies have sought to explore the concept of brain lateralization as it relates to motor control and language. Lateralization may be defined as “hemispheric superiority for serving language” (Bhatnager, 2013). Typically, in 96% of people worldwide, language function is carried out by the left hemisphere (Rasmussen & Milner, 1977). Evidence supporting this high percentage derives from the high incidences of aphasia resulting from left hemisphere damage, as well as a lack of research corresponding with aphasia following right hemisphere lesions. In a study completed by Rasmussen and Milner (1977), the language centers of both dominant hemispheres were evaluated through a sample of 140 right-handed individuals. Their outcome asserted that of these subjects, only 4% represented language function in the right hemisphere. The findings correspond with data compiled during a systematic review of 588 individuals undergoing Wada tests in order to document language and memory lateralization. Of these individuals, 6% were classified as right hemisphere dominant (Moddell, Lineweaver, Schuele, Reinholz, & Loddenkemper, 2009). The frequency of right-hemisphere cerebral dominance is approximately 1 in 10 individuals (Knecht, Jansen, Frank, Randenborgh, Sommer, Kanowski, & Heinze, 2002). Although previous research has suggested the appearance of aphasia in right hemisphere individuals is more prevalent in left-handers, recent data compiled by Morrow-Odom & Swan (2013) demonstrates that this type of manifestation is still considered a rare clinical occurrence. Therefore, the minute percentage of individuals who meet this criterion are recognized as atypical.

Previous research has found the presence of apraxia to commonly occur in right-handed individuals following left cerebral hemisphere lesions. Apraxia may be defined as an
“inability to perform or inappropriateness in performing actions that cannot be attributed to paralysis or other primary motor deficits, nor to impaired comprehension or motivation” (Archibald, 1987). However, the documentation of lesions in left-handed individuals, has found that in cases of right hemisphere damage, the association between aphasia and apraxia is rare. According to Archibald (1987), and Margolin (1984), this is due to the variable atypical representation of language in these individuals. Furthermore, because apraxia has typically been associated with aphasia from left hemisphere damage, research suggests the possibility of shared neural structures between the two (Archibald, 1987). For individuals who are atypically lateralized for language, the representation of language and praxis are thought to be neurologically independent. These findings have prompted researchers to further examine the characteristics associated with reversed hemispheric organization. In a study completed by Archibald (1987), two left-handed patients with right hemisphere damage were evaluated. Following the administering of the Rey-Osterrieth Figure Test, data for impaired visuospatial function was noted. In cases of atypical hemispheric functioning, typical right hemisphere tasks such as visuospatial and memory skills follow a pattern consistently documented in left hemisphere damage. These findings therefore, provided evidence to argue against the presence of reversed cerebral lateralization in both individuals. Given the presence of reversed lateralization, the execution of these tasks would have been intact (Archibald, 1987).

Although previous research demonstrates the rare but possible occurrence of atypical language lateralization, literature regarding knowledge of how these communication breakdowns manifest following a diagnosis of aphasia is lacking. According to Knecht et al., (2003) the limitations in the current research correspond to our preliminary knowledge of right-hemisphere language dominance and underlying mechanisms. Further knowledge is dependent upon the documentation of individual cases. With an estimated 50 million Americans currently experiencing cognitive communicative disorders (Bhatnager, 2013), these findings have direct applications to the clinical understanding of how the brain executes language in these individuals.

Purpose
Specifically, this study sought to determine the following: To what extent has the right hemisphere (RH) preserved function? Has the left hemisphere (LH) assumed control over the execution of typical RH tasks? Given that the language areas of the RH are damaged, how do these deficits differ from those seen in typical LH aphasia?

Methodology
This research was guided by a prospective single-subject study. As evidenced by Paul & Cascella (2007), single-subject designs are significant in research that is focused on low-incidence disorders. By adopting this method, it was possible to construct an in-depth analysis of the participant’s skills from a collection of qualitative and quantitative data. Given the limited amount of cases for atypical language lateralization, this design was implemented in order to develop a greater understanding of how the brain executes language in these individuals.

Participant
The participant (PG) was a 60-year-old male residing at the Royal of Cotuit Nursing and Rehabilitation Center in Mashpee, MA. At the time of the study, PG was status post RH cerebral vascular accident (stroke) with diagnosed Broca’s aphasia and accompanying left hemiparesis (left-side weakness). Information concerning PG’s medical history and lesion location was requested and acquired from the facility at which testing took place. In December 2012, PG was admitted after being found unresponsive with left-sided weakness. An imaging method known as computerized tomography (CT) was administered in order to form a detailed scan of PG’s neural (brain) structures from the top of the brain to the bottom. The scans noted the presence of cerebral infarctions, a form of stroke caused by the inability of the blood vessels to supply blood to the brain. Affected areas of the brain included the inferior (lower) right frontal lobe, anterior (front) temporal lobe, and a structure responsible for the transportation of blood to the brain known as the middle cerebral artery (MCA). The presence of swelling was reported on the left lateral ventricle; however, there was no indication of a midline shift, meaning that pressure did not cause PG’s brain to shift beyond the central line. Additional lacunar infarcts or strokes in the deeper structures of the brain were observed within a neural structure called the corona radiata. Hypodensities, or areas of softened brain tissue, were reported in the white matter of both cerebral hemispheres as a result of these lacunar infarcts. Carotid Doppler testing was performed in order to assess blood flow in the carotid arteries of PG’s neck. Results found 19% stenosis (narrowing) of the right internal carotid artery and 49% stenosis of the left internal carotid artery. A video swallow completed by speech pathology found the development of pneumonia (PNA) in the left lower lung (LLL), and mild-moderate oropharyngeal dysphasia, a disorder that creates difficulty in initiating a swallow. Reports of the neurologist findings indicated that PG was mute but able to follow commands. There was no documented speech-language evaluation report at the time of testing. Preceding the occurrence of his stroke, PG had no known history of...
Materials and Procedures
In order to address the research questions, language and cognitive abilities were examined through a battery of manual and iPad related tests. To establish inter-rater reliability for measures requiring subjective judgment of accuracy/inaccuracy, two examiners were used. Following testing, the obtained data was categorized into typical right and left frontal, parietal, and temporal functions and used to examine the functionality of skills typically associated with the right hemisphere. Measurements of frontal lobe functions included tasks associated with gesture recognition, the sequencing of complex movements, executive functioning and selective attention. Tests associated with functions localized to the temporal lobe assessed the recall of nonverbal stimuli including musical melodies, recognition of color, auditory comprehension, and word recognition. Parietal lobe data focused on spatial and right/left side awareness as well as visuospatial ability, constructional skills, writing, and reading comprehension. In addition to these assessments, a test of oral and limb apraxia was administered in order to document components of PG’s respiratory and non-respiratory oral praxis (movement) and ideomotor (involuntary motor) skills. Given that our participant was reversed for language production and comprehension, through these tests we would expect to see the execution of tasks typically localized to the right hemisphere to be intact. This would indicate the control of the LH over these abilities.

Frontal Lobe Tests
*Stroop Color and Word Test.* The Stroop Color and Word Test (Golden & Freshwater, 2002) is a neuropsychological measure designed to assess executive functioning in addition to selective attention and cognitive flexibility. The participant was presented with a series of words in one of four colors: red, yellow, green or blue. Given a time limit of 30 seconds, PG was asked to identify the color of the words as quickly as possible. As the stimuli was presented one at a time, PG needed to correctly identify the first word before proceeding to the next. This test was administered twice, once with no interference and once with. In addition, the number of items correct was recorded and compared with a possible score of 20. Lower scores indicated poorer performance.

*Alternating Trail Making Test.* The Alternating Trail Making Test (Lease, 2011), created as a measure for visual attention and task, presented PG with a series of randomized letters and numbers displayed on the iPad. Stimuli included letters A-L and numbers 1-12. PG was asked to connect the stimuli in order, alternating between letters and numbers (1, A, 2, B, etc.). Poor performance indicated impairment localized to the frontal lobe.

*Forward and Backward Manual Visual Span.* The Manual Span (WhiteAnt Occasional Publishing, 2014) measures executive function and selective attention and sequencing. PG was presented with a series of blocks displayed on the iPad. Following the examiner’s model, he was asked to repeat the sequence in the same succession as the model. In the administering of the Backward Span, PG was presented with the same series of blocks. However, in following the examiner’s model, PG was asked to tap the blocks in the reverse order starting with the last block the clinician had touched and ending with the first. Performance and timing were recorded and scored out of a 5 on both the forward and backward subtests.

*Boston Assessment of Severe Aphasia (BASA).* The gesture recognition subtest taken from the BASA was administered as a measure for recognition of nonverbal stimuli. PG was asked to match two pictures to their appropriate gestures. Answers were scored as fully communicative affective (G2A) or partially communicative affective (G1A). In instances where perseveration or the repetition of a response was noted, “P” was recorded. Given the influence of aphasia on PG’s verbal abilities, all answers were marked as “G” for gestural response.

Temporal Lobe Tests
*Cognitive Linguistic Quick Test (CLQT).* The story-retelling subtest from the CLQT was administered to PG as a measure for auditory comprehension (a typical LH function). Following the examiner’s verbal recount of a story, a series of 6 paired yes/no questions were presented to PG. In order to attain a correct response, PG was required to accurately answer both questions in a pair. The maximum score for this subtest was a 3 with poor performance indicated through a lower score.

*BASA:* The BASA was administered to identify preserved auditory comprehensive skills by scoring PG’s gestural, perseverated, and affective responses on subtests that required the identification of the correct month following verbal cuing. In addition, PG was asked to follow a series of verbal commands and match pictures of various actions to corresponding words.

*BD�E:* Auditory and verbal comprehension was assessed through subtests including word discrimination, complex
ideational material, and understanding written language. For these tasks, a series of yes/no questions were presented to PG regarding implied information not readily in view. In addition, PG was administered a list of words verbally and asked to match them to corresponding pictures. Scores for these functions were recorded and compared to a percentile norm. Color recognition (typical RH task) was also measured through a subtest that required PG to identify and match a series of colors given verbally to corresponding pictures. Scores were reflected out of a possible 12 points.

Aphasia Diagnostic Profile (ADP): The recognition and recall of musical tones (typical right hemisphere task) was assessed through a subtest that required PG to recognize and produce a series of tunes including “Happy Birthday,” “Rock-a-Bye Baby,” and “America, The Beautiful.” For each song accurately recognized, produced, and carried, 3 points were given. Scores reflected a maximum of 9 points. The understanding stories subtest of the ADP was administered as well as a measure for auditory comprehension. Three stories, labeled “A,” “B,” “C” were given verbally to PG and followed by a series of yes/no questions about stated and implied information. A maximum score of 10 was possible.

Parietal Lobe Tests

CLQT: As a measure of visuospatial abilities and neglect, the symbol cancelation subtest was administered. With a time constraint of 2 minutes, PG was given a model symbol and asked to eliminate all identical symbols on a following page. Performance was timed and scores were compared with a criterion cut score for age.

BASA: A subtest that required PG to reproduce the drawing of a man following a model was timed and scored according to his gestural, perseverated, and affective responses. Poor performance for this task was indicated through missing body parts or neglect to one side of the figure. This subtest was used as a measure for constructional and visuospatial abilities. Additionally, a subtest for writing (typical LH task) was administered.

BDAE: Body part identification and right/left discrimination components of the BDAE were given as assessment measures for spatial awareness and neglect. For the L/R awareness subtest, scoring reflected a maximum of 20 points. Body part identification was scored out of 18. Missed or inaccurately identified body parts demonstrated poor performance.

Clock Drawing Test Protocol: This test was administered on the iPad as a measure of neglect. PG was asked to draw a clock and place the hands at the time ten after eleven. Scoring reflected the correct orientation, representation, and legibility of the clock.

Findings

Frontal Lobe Findings

Overall findings of the frontal lobe indicated that specific skills associated with typical right hemisphere function were intact. Data obtained from the gesture recognition subtest of the BASA demonstrated a maximum score of G2A on both stimuli. On the Manual Visual Span, PG obtained a span of 4/5 on both the forward and backward components. In terms of standard scores for this test, a normal forward span is considered 5 while a normal backward is 4. PG scored one below the standard for forward and within norms for backward when he was asked to manually reproduce a pattern, in the reverse order, from memory. On the Alternating Trail Making Test, scores were dependent on the ability to alternate lettered and numbered blocks in an organized fashion. Difficulty in alternating stimuli into a coordinated sequence was noted. PG organized numbers and letters separately and in some instances misplaced or excluded blocks. Finally, data obtained from the Stroop Color and Word Test demonstrated that when no interference was presented, PG correctly matched 20 targets within the time allotment of 30 seconds. With interference from color, PG demonstrated a score of 2/20 correct in 30 seconds.

Temporal Lobe Findings

Following temporal lobe testing, the obtained data was classified into either typical right or typical left hemisphere function. On the assessment of auditory comprehension (a typical left hemisphere task), a series of subtests from the BASA, ADP, CLQT and BDAE were administered to PG. The largest number of deficits noted were those found in tasks where PG was required to answer a series of questions following the examiner’s verbal recount of a story. On these tasks, significant perseveration was noted in PG’s continuous response of “yes.” Difficulty in this skill was reflected in the story recall subtest of the CLQT, for which PG scored a 0/3, as well as an ADP subtest for which a score of 0 was obtained for all three stories. In instances where PG was required to match written words to their corresponding picture, he was able to do so provided there was visual stimuli present. This is illustrated in his score of 9/10 on the word recognition subtest of the BDAE and 2/2 on the written word to picture portion of the BASA.

Testing on typical right temporal lobe functions were indicated through subtests of the BDAE and ADP. In terms of color recognition, PG scored a maximum 12/12 through his accurate identification of all colors. His recognition and recall
of musical tones is reflected in a score of 3/9. In regards to the recognition of tunes, PG recognized “Happy Birthday,” “Rock-a-Bye Baby,” and “America, The Beautiful.” In addition, he was able to produce the tunes in unison with the examiner. However, when the examiner faded cuing, PG was unable to continue the melody alone.

Parietal Lobe Findings
Overall data analysis for parietal lobe testing indicated that typical right hemisphere function for this area was intact. Data obtained from Clock Drawing demonstrated PG's acknowledgement of numbers on both sides of space. However, in terms of the correct representation of time, PG scored a 0/1. Instead of placing the hands at the correct time of 10 past 11, PG placed the hands at 3 o’clock. On symbol cancellation, PG finished in 1:02 seconds with a score of 11 and paid adequate attention to symbols on both sides of space. When compared to the criterion cut score for his age, his performance was considered within normal limits. On testing that assessed visuospatial and constructional skills, PG demonstrated awareness of both sides of space by producing complete pictures that represented both the left and right sides of the body. On Body Identification on the BDAE PG scored a 16/18, placing him in the 60th percentile for aphasia severity. PG’s performance on the writing subtest of the BASA was reflected in his score of 0/1. During this assessment, PG shifted from print to cursive resulting in a signature that was partially illegible.

Discussion
This case study sought to measure the cognitive and language function of both the right and left cerebral hemispheres in order to determine the extent to which PG's left hemisphere may have lateralized typical RH tasks. Results indicated that although the participant experienced damage to areas of both the frontal and temporal lobe, typical right hemisphere cognitive skills associated with these areas appeared intact.

Through frontal lobe data, we found functions of non-verbal communication and visual memory to be intact and maintained by PG’s LH. Following the administration of the Span Test, it was noted that PG scored within norms for backward visual span where he was asked to manually reproduce a pattern from memory in the reverse order. Additionally, during the gesture recognition subtest of the BASA, PG was adequately able to match picture stimuli to their corresponding gestures. Given PG’s diagnosis of right frontal damage, the ability to recognize gestures should have been impaired. Poor performance on the Stroop Word and Color as well as the Alternating Trail Test provided further evidence for PG’s reversed cerebral lateralization. Deficits in selective attention were documented following the completion of Stroop. In the presence of interference, PG was unable to accurately identify the targets. In addition, his continuous hitting of the target “yellow” even when “yellow” changed to a new color demonstrated the presence of perseveration. Perseveration may be defined as the “uncontrolled and unaware repetition of an earlier response after a change in stimuli tasks” (Bhatnager, 2013). PG’s inability to switch from one stimulus to the next indicated that he was unaware of his error. Deficits in the ability to sequence complex movements was also noted as PG was unable to integrate numbers and letters into an ordered pattern during the Alternating Trail Making Test.

Data compiled from temporal lobe assessments demonstrated that functions of color recognition and recognition of musical tones were intact and maintained by PG’s LH. Though PG was unable to carry a tune on his own during the singing portion of the ADP, his recognition of the three songs and attempt to produce the melody in unison with the examiner indicated that this skill was preserved. These findings, combined with his color recognition scores on the BDAE, demonstrated that the LH was processing and executing these typical RH skills. Furthermore, the data from these subtests coincide with the results of PG’s CT scan documented infarctions to the anterior temporal lobe. Given this type of damage, deficits in these two temporal functions should have been noted. In addition to musical and color recognition, an assessment of auditory comprehension (typical LH task) was conducted. In cases of typical Broca’s aphasia following LH damage, auditory comprehension is relatively spared (Coppens, et al., 2013). However, in the presence of reversed cerebral lateralization, we expected that deficits in PG’s auditory comprehension skills would be impaired. Analysis of data obtained from subtests of the BDAE, ADP, CLQT, and BASA established deficits in PG’s ability to separate and identify stimuli following verbal input. Impairments in PG’s use of contextual information in the interpretation of events were also noted, as PG was unable to listen to a story or paragraph and process its events. Perseveration was observed across all tasks that involved PG to answer yes/no questions following a story. In these instances, PG responded with a continuous “yes.” These findings correspond with deficits to the left temporal lobe, a characteristic of typical Broca’s aphasia. However, because of PG's pattern of reversed cerebral dominance, these findings indicate damage to PG’s right temporal lobe.

In the distribution of tests associated with parietal lobe functions, it was expected that following the completion of these tasks, the presence of hemispatial neglect would be noted. Neglect may be defined as “the inability to detect, identify, or move objects in the contralesional (left) side of
space, even in the absence of sensory or motor deficits (Saj, Fuhrman, Vuilleumier, & Boroditsky, 2014). Following right hemisphere lesions, these common deficits interfere with the individual’s ability to generate normal representations of contralesional figures (Bhatnager, 2013). In the analysis of the findings however, PG’s ability to acknowledge both sides of space on subtests such as clock drawing and symbol cancellation indicated that his internal representation of objects and people in space were intact. Additionally, PG’s detail to the left side of his drawing in the BASA subtest indicated the absence of neglect. The implications of this data correspond with an earlier research question regarding the nature of PG’s RH following his stroke. Due to the absence of neglect in all of the associated tasks in addition to PG’s medical reports, it can be determined that the typical RH skills of spatial awareness and constructional ability remained undamaged. Following our participant’s performance on the writing subtest, results indicated the possible presence of apraxia, a disorder characterized by distorted, imprecise, or incomplete letter formation (Bhatnager, 2013). However, following testing it was taken into consideration that PG’s left side hemiparesis (weakness) requires him to write with his right non-dominant hand. In addition, the CT scan administered prior to testing did not note any damage to the left parietal lobe, the area in which writing ability is localized.

As mentioned above, the presence of apraxia often manifests following brain lesions localized to the LH in both right and left handed individuals. Data obtained from the TOLA indicated components of oral apraxia in PG. His performance and results on the non-respiratory component of this test correspond with his atypical representation of language in the right hemisphere. According to Archibald (1987), the representation of praxis or ability to perform learned gestures is typically localized to the left hemisphere. Some individuals, though rare, have been found to represent both language and praxis in the right hemisphere (Archibald, 1987). Following the distribution and completion of the TOLA, PG’s inability to accurately execute non-respiratory tasks such as “bite an apple” indicates the lateralization of praxis in addition to language to his RH. Following the completion and analysis of cognitive and linguistic testing, the data demonstrated that PG experienced a severe Broca’s aphasia with components of oral apraxia and agraphia, as well as auditory comprehension deficits. In addition, the findings indicated that PG’s LH had assumed control over typical RH functions, including gesture recognition, verbal memory, color recognition, and the recognition of nonverbal stimuli.

Conclusion
As clinicians in the field of speech-language pathology, decisions regarding intervention methods are dependent upon the clinical expertise and external evidence found in the literature. In order to provide high-quality and individual based services, knowledge of the way in which communication breakdowns manifest is crucial. However, in rare cases such as PG’s where the literature is lacking, single-subject designs are beneficial in creating a foundation of knowledge from individual patient analyses. Owing to the rare occurrence of atypical language lateralization, the findings obtained during this study have direct applications to the clinical understanding of how the brain executes language in these individuals. Furthermore, the implications of this research are influential towards the future expansion of intervention methods in the domain of aphasia and related disorders. Although further research on the right hemisphere’s function following this type of language deficit is necessary, these findings will help to build a foundation in the literature as well as in the field of speech-language pathology.

References


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**About the Author**

Emily Manton is a senior double majoring in Communication Disorders and English. Her research project was completed in the summer of 2014 under the mentorship of Dr. Suzanne Miller (Communication Disorders) and made possible with funding provided by an Adrian Tinsley Program summer research grant. Emily presented this paper at the National Conference on Undergraduate Research in 2015. She plans to pursue her M.A. in speech-language pathology in the fall of 2015.