Assessing the Bilingual Advantage: Is Support Found in Aphasia Patients?

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Abstract

Aphasia is a language disorder caused by brain damage that can impair an individual's cognitive skills and executive functioning, as well as their ability to communicate effectively. Executive functioning is an umbrella term describing various cognitive processes, including skills such as inhibition control, cognitive flexibility and working memory. The bilingual advantage states that learning two or more languages will increase executive function and cognitive control.

Currently, there is limited research regarding the bilingual advantage within the aphasia population. Research has predominantly focused on monolingual individuals or has not looked at bilingualism as a specific variable.

This study aimed to examine the cognitive-linguistic abilities of bilingual and monolingual individuals within the aphasia community; the researchers hypothesized that they would observe more efficient executive functioning in the bilingual group. Adults diagnosed with aphasia secondary to stroke completed a modified Language Experience and Proficiency Questionnaire (LEAP-Q) about their language background and completed two computerized executive functions tasks, the Stroop Color and Word Test (SCWT) and the Wisconsin Card Sorting Test (WCST), which assess inhibition, working memory, and cognitive flexibility.

Results indicated that the bilingual group did not demonstrate the bilingual advantage. It was found that, on average, monolingual participants experienced fewer total errors and perseverations errors compared to bilingual participants. However, a larger sample size more representative of the monolingual and bilingual aphasia populations is needed to further support or refute the bilingual advantage. Additionally, it would be

beneficial to administer the assessments with the participants rather than independently via online, pre-existing tasks to accommodate each participant's abilities best.

Literature Review

Aphasia is a language disorder that can impair an individual's ability to communicate effectively. It is estimated that in the United States, there are 1 million people who have acquired this diagnosis through an array of brain injuries, with 180,000 people being diagnosed each year (Aphasia, 2017). Most previous research regarding the aphasia population in the field of Speech-Language Pathology involves monolingual participants; however, most of the world's population speaks more than one language. In the United States alone, there are more than 60 million residents over the age of 5 years old who speak at least two languages (U.S. Census Bureau, 2015). Though there has been a recent uptick in studies with bilingual participants, there is a gap in the research concerning the bilingual population with acquired aphasia.

Language processing abilities have been found to be related to executive functioning (Ratiu & Azuma, 2017). Executive functioning is an umbrella term for the set of cognitive processes that control the actions and thoughts of individuals. Executive functioning allows an individual to plan, multitask, sequence events, pay attention, problem-solve, and focus on tasks (Ratiu & Azuma, 2017). Two of these executive functioning skills that are highly related to language processing are cognitive flexibility and inhibition.

Cognitive flexibility is an individual's ability to switch perceptions, ideas, and thinking strategies, e.g., thinking about one concept in multiple ways. (Lange et al., 2017). As an individual redirects their attention to relevant stimuli, while thinking about multiple

concepts, that is known as cognitive flexibility (Lange et al., 2017). Inhibitory control is an individual's ability to suppress natural impulses to stimuli and select an appropriate behavior that is consistent with completing a task (Diamond, 2013). Inhibitory control is the cognitive process of suppressing an action, thought, or feeling, and this ability to restrain from acting on an impulse is essential for self-control. The individual's ability to avoid responding inappropriately due to their awareness of the task and the attention required to be consistent with completing the task is known as inhibitory control.

A growing body of research has found that proficiency in a second language may contribute to improved executive function and cognitive control. Since bilingual individuals must manage both languages simultaneously, it is posited that the bilingual brain relies on executive processes such as interference control, inhibition, and switching to do so (Marian & Shook, 2012). This constant alternation and coordination of two languages change the associated brain regions leading to increased cognitive flexibility. Researchers within this field have coined this the bilingual advantage. Limited research has been done on the possibility of a bilingual advantage in individuals with aphasia, and results have been contradictory, with some studies finding evidence of this advantage (e.g., Dekhtyar, Kiran, & Gray, 2020) but others failing to do so (e.g., Faroqi-Shah et al., 2018).

Although there has been significant interest in the investigation of bilingual cognitive advantages, there is far less evidence to suggest its presence in individuals surviving a neurological impairment. Therefore, this study aims to assess the executive functioning skills of bilingual and monolingual individuals with aphasia using executive functioning tasks, such as the Stroop Color and Word Test (SCWT) and Wisconsin Card

Sorting Test (WCST).

Executive Functioning

Executive functioning is an umbrella term that describes a set of cognitive processes which aid in the facilitation and achievement of goal-directed behavior. It encompasses complex and essential skills that contribute to many domains in life (e.g., school and work) in addition to social and psychological development. According to recent literature, there are three agreed-upon core executive functions: inhibition control, cognitive flexibility, and working memory (Diamond, 2013). Given the proposed evidence of enhanced abilities amongst bilingual individuals, inhibitory control and cognitive flexibility will be solely discussed in this paper.

Inhibitory control is defined as the ability to suppress a natural impulse to internal or external stimuli and select an appropriate behavior that is consistent with completing a task (Diamond, 2013). In addition, inhibitory control plays a significant role in other executive functions, such as focused attention and self-regulation. Impairments in inhibitory control result in the individual's inability to inhibit competing and irrelevant information. Response inhibition is the cognitive process of suppressing a learned action, thought, or feeling and is essential for self-control.

Cognitive flexibility is conceptualized as an individual's ability to switch perceptions, ideas, and thinking strategies (e.g., thinking about one concept in multiple ways; Lange et al., 2017). Further, cognitive flexibility is an individual's ability to switch between thinking about various concepts simultaneously by redirecting their attention to relevant stimuli while thinking about multiple concepts (Lange et al., 2017). Deficits in this area affect one's ability to switch and manage between multiple tasks, as well as adapt

to changing environments.

When an individual is unsuccessful in communicating verbally and needs to switch to a different communication modality (e.g., gestures, written language) cognitive flexibility is necessary in order to switch communication modalities (Purdy, 2002). Individuals with aphasia may demonstrate difficulty in communicating verbally and cognitive flexibility is required in order to convey their message to a communication partner. Similarly, studies have shown that executive functioning skills, such as inhibitory control, may be negatively affected in individuals with aphasia. The communication skills of an individual with aphasia may be impaired due to the lack of inhibitory control. For example, during a conversation, inhibitory control allows an individual to refrain from responding inappropriately by first thinking about what they want to say. According to Fridriksson et al. (2006), inhibitory control allows individuals to retain information from their communication partner, inhibit an inappropriate response, and plan how they will respond. This person is able to accomplish these tasks by relying on their working memory, inhibition control, and planning abilities. If an individual's inhibition control is impaired due to aphasia, deficits in functional communication may be exhibited (Fridriksson et al., 2006).

Executive Functioning in Aphasia

Though communication deficits are the presenting hallmark of aphasia, people with aphasia additionally depend on executive functioning skills to communicate when deficits occur in their linguistic abilities (Purdy, 2002). Purdy (2002) examined executive functioning skills in individuals with aphasia by assessing the accuracy, efficiency, and speed of their performance in various tasks designed to assess cognitive flexibility. The

Wisconsin Card Sorting Test (WCST) was utilized to compare cognitive flexibility in individuals with aphasia and healthy participants. The WCST required the participants to classify a presented card based on its color, form, or number of shapes. For example, if the participant was presented with a card with one red triangle and they were matching according to shape, they would select the corresponding card with the triangle. This study revealed that the control group of healthy participants performed well in the WCST task in terms of accuracy whereas the aphasia group demonstrated difficulties in cognitive flexibility, the ability to shift attention between one task and another (Purdy, 2002). In the WCST, the individuals with aphasia struggled to change the plan and apply the new rule and demonstrated difficulty shifting attention to two tasks simultaneously. The results from this study support the notion that individuals with aphasia present with impaired executive functioning skills, specifically cognitive flexibility.

Individuals with aphasia have difficulty switching their attention while completing a task (Ratiu & Azuma, 2017). Fridriksson (2006) assessed cognitive flexibility by administering two executive function tests, the Wisconsin Card Sorting Task and the Color Trails Test, with 25 participants diagnosed with aphasia secondary to a cerebrovascular accident (CVA). The Color Trails Test requires sequencing, planning, cognitive flexibility, working memory, and sustained attention (Fridriksson et al., 2006). This test was administered to participants with aphasia and the results revealed that individuals with mild aphasia required fewer prompts than those with severe aphasia. This cognitive task measures the ability to develop and preserve a problem-solving strategy across altering stimulus conditions. This provides a comparison of cognitive flexibility skills along the range of impairment levels. Individuals with mild aphasia demonstrated a

more intact cognitive flexibility compared to individuals with a more severe form of aphasia (Fridriksson, 2006). Additionally, the majority of the participants did not complete a single category on the WCST, which may have contributed to the participants' inability to actively utilize their working memory to match the current category long enough to complete the ten items and proceed to a different category (Fridriksson, 2006). The researchers concluded that the number of items correct, and the conceptual level responses were the valuable scores for assessing executive function because there were limited conclusions to be made based on the number of categories completed. The results support the correlation of executive functioning and functional communication abilities demonstrated by individuals with aphasia. This notion has the potential to explain the differences between performance on aphasia assessments and functional communication ability (Fridriksson, 2006). Additionally, researchers of this study suggest that executive functioning and functional communication ability correlate in people with aphasia and that the severity of aphasia may be a factor in measuring the cognitive flexibility of this population.

Executive Functioning and the Bilingual Advantage

In the past few decades, an increasing number of studies have been conducted to determine the presence of a bilingual cognitive advantage. The bilingual advantage theory posits that bilingual populations outperform monolingual individuals in various cognitive domains, such as executive functioning, attention, and working memory (van den Noort et al., 2019). This postulate is based on the assumption that individuals who speak more than one language must inhibit or control their actively competing languages and thus are constantly engaged in cross-linguistic activation during language processing (Poarch &

Krott, 2019). Further, researchers speculate that bilingual and multilingual individuals must rely on their executive functioning skills (e.g., inhibition and cognitive flexibility) at a greater degree and/or demonstrate significant cognitive control compared to those who only speak one language. In others words, a cognitive bilingual advantage exists because bilinguals have to manage simultaneous interference from their languages (van den Noort et al., 2019). Despite the growing body of research on this theoretical framework, researchers have been unable to definitively state whether or not the bilingual advantage exists. Results of various studies have either been in support of or against its existence.

Research into this idea began relatively recently, around 2008. Bialystok and colleagues (2008) observed that bilingual participants had lower error rates than monolingual participants during certain executive function tasks, including the Stroop color naming task. Error rates among the young monolingual group was 2.1%, whereas the young and older bilingual group performed with less than 1% of errors.

Additional research also found that Turkish-English bilingual individuals demonstrated faster response times on the Trail Making Test, which measures cognitive control and flexibility. Compared to Turkish monolinguals, bilinguals' response times were 10.6 seconds faster when alternating between numbers and letters in consecutive order (Secer, 2016). Studies involving bilingual children have also revealed considerable cognitive characteristics not present among children who speak one language. Additional research conducted by Bialystok found that bilingual children consistently outperformed their monolingual peers on tasks that require high levels of cognitive control as they were better able to resist distractions and attend to the task involved (Penn et al., 2010).

Schweizer et al. (2012) conducted a study involving neurological imaging, which

found that even though bilingual patients with Alzheimer's had more significant brain atrophy than monolingual patients, both groups performed at the same level of cognitive functioning. It was believed that bilingualism was protective for this group because their cognitive impairment was not as severe as expected based on the imaging. Kousaie and Phillips (2017) implemented behavioral and electrophysiological measures to assess cognitive skills and found that bilingual participants had faster response times on items with increased cognitive conflict (i.e., incongruent tasks). This decrease in reaction time suggests that the bilingual participants are able to detect and process conflicting information faster than monolinguals. Reduced rate of errors and processing time in a variety of tasks across studies has been determined to be evidence in support of a bilingual advantage.

Although there is support for the bilingual advantage, there is also a considerable amount of research that shows bilinguals do not have any cognitive advantages compared to monolinguals. When healthy bilingual and monolingual adults completed the Non-linguistic Triad Task (NLTT), which consisted of congruent and incongruent (matching and nonmatching stimuli) tasks to assess cognitive abilities, no significant difference was discovered (Dekhtyar, Kiran, & Gray, 2020). Additional research revealed that monolingual groups had fewer errors when compared to bilingual peers (Kousaie et al., 2014). Results from Kousaie et al. (2014) were inconsistent across tasks, showing a minimal bilingual advantage on the Stroop task but no advantage on other tasks assessing interference, inhibition, working memory, and cognitive flexibility. The minimal advantage may have been due to the language component of the Stroop task, requiring participants to use receptive and expressive language skills. Due to the variability in results across tasks measuring different aspects of executive functioning, these researchers have determined

that a universal bilingual advantage theory cannot be supported.

The bilingual advantage is still quite controversial, given the inconsistent evidence found within the current literature. Evidence disputing the possibility of the bilingual advantage indicated by Dick et al. (2019) found that, among bilingual and monolingual children, there was no difference in executive functioning and cognitive flexibility when completing the Flanker Inhibitory Control and Attention Test and Dimensional Change Card Sort. However, advocates for the bilingual advantage contend that executive functioning is enhanced due to the constant involvement of language use and its effect on increased neural connectivity. This is purported by executive functioning tasks conducted by Biaylstok et al. (2008), Secer (2016), and Kousaie and Phillips (2017), who found bilingual adults to have fewer error rates and faster response times. Performance by bilingual children, who demonstrated noticeably stronger inhibitory control and attentive skills, further supports this claim. The results of these studies have been extended to propose that mental flexibility within bilingual populations would be present even under conditions of acquired language impairment, such as aphasia.

Bilingual Aphasia

The recovery process in individuals with aphasia differs between monolingual and bilingual populations. One key difference between the two groups is that bilinguals must regain linguistic abilities in more than one language. Various factors influence bilingual recovery, such as the age of acquisition of each language, proficiency in each language before diagnosis, and the language/s being treated in therapy (Ansalado & Saidi, 2014). These factors can influence how the bilingual individual recovers linguistic skills in each

language.

Executive Functioning and Bilingual Advantage in Aphasia

Researchers have conducted studies with bilingual adults who have suffered brain injuries to determine if they possess stronger executive functioning skills than monolingual adults who suffered from similar injuries. It is believed that management of attention and inhibition when balancing multiple languages pre-injury would lead bilingual adults with brain injuries to preserve their cognitive abilities (Bialystok, Craik, & Freedman, 2007). In adults with brain injuries, if there is a bilingual advantage, their cognitive functioning would be greater than that of matched monolingual adults; these adults may demonstrate cognitive skills typical of a healthy, uninjured adult.

The results of several studies provide evidence in support of a bilingual advantage in this population. When assessing inhibitory control in individuals with aphasia using a computerized NLTT, the bilingual group demonstrated stronger ability through reduced reaction time (Dekhtyar, Kiran, & Gray, 2020). Chertkow et al. (2010) found that when comparing monolingual and bilingual individuals with Alzheimer's disease, there is a minimal delay in onset in bilinguals by one year; however, they found a more significant delay in onset when the individual spoke three or more languages. Their findings demonstrate that bilingualism may result in some cognitive protection but show stronger evidence for a possible multilingual advantage. Lahiri et al. (2020) assessed the language abilities of bilingual and monolingual individuals by administering the Bengali version of the Western Aphasia Battery (BWAB) and assessing their aphasia quotient (AQ), a number corresponding to the severity of

an individual's aphasia, one week and three months post-stroke; it was found that after the second administration, the bilingual group demonstrated greater recovery compared to the monolingual group. When assessing executive function and working memory through conversational tasks, it was found that bilingual individuals with aphasia demonstrated better skills in topic maintenance and flexibility than their monolingual counterparts (Penn et al., 2010). This research suggests that the bilingual advantage may exist in the aphasia population as well as healthy populations.

There is also a substantial amount of research to demonstrate that there is not a bilingual advantage among adults who have sustained a brain injury. Researchers conducted a study with three groups of adults with aphasia, 2 bilingual groups speaking English and another language and 1 monolingual English, completing the Stroop Task and word-retrieval tasks to assess their cognitive control and found that there was a cognitive advantage in only 1 of the 2 bilingual groups, suggesting that cognition is impaired and there may not be a significant bilingual advantage for cognitive functioning (Faroqi-Shah et al., 2016). Hope et al., (2015) analyzed scores from a portion of the Comprehensive Aphasia Test (CAT) to determine a variety of linguistic abilities of bilingual and monolingual aphasia patients and discovered that the bilingual group's score was lower than that of the monolingual group. These conflicting findings indicate that this area requires further research to evaluate the cognitive abilities of bilingual people with aphasia to determine the existence of the bilingual advantage.

Aims

The dynamic relationship between bilingualism and executive functioning has

been heavily researched; however, there is much less evidence to suggest whether the bilingual advantage is present in people with aphasia. Therefore, this study aims to examine the cognitive-linguistic abilities of bilingual individuals within this population. In addition, it aims to determine whether bilinguals with aphasia will exhibit greater inhibition control and cognitive flexibility than monolinguals with aphasia on cognitive and executive function tasks. The researchers hypothesized that more efficient executive functioning would be observed in the bilingual group based on the current working theory surrounding the bilingual advantage. The current research addressed three main questions. First, will the bilingual individuals have better interference and/or inhibition abilities when performing cognitive tasks? Second, will there be more efficient executive functioning in the bilingual group? Lastly, does this study support the bilingual advantage theory and its relation to individuals with cognitive impairments?

Methods

Participants

Researchers recruited 6 participants who were receiving services at the Kean University Center for Communication Disorders (KUCCD) for the study. Participants were bilingual and monolingual adults diagnosed with various types of aphasia ranging from 46 years old to 78 years old and from 1 year post-stroke to 20 years post-stroke. Two monolingual and four bilingual participants took part in the study. Bilingual participants all spoke English and a variety of one or two other languages. The order of acquisition of English and other languages varied across the group of bilingual participants. One bilingual participant was a simultaneous language learner, while three were sequential language learners, all learning English later in their lives (see Table 1).

Participant #	Age	Type of Aphasia	Years Post Stroke	Language Status	Languages Spoken
M1	67	Moderate Expressive and Receptive Aphasia	6	Monolingual	English
M2	78	Mild Anomia Aphasia	6	Monolingual	English
B1	46	Severe Expressive Aphasia	1	Bilingual	English and Spanish
B2	57	Severe Expressive Aphasia, Dysarthria, and Cognitive Deficits	4	Bilingual	Portuguese, French, and English
B3	63	Transcortical Motor Aphasia	3	Bilingual	Spanish and English
B4	62	Moderate Expressive Aphasia	20	Bilingual	Mandarin Chinese and English

Table 1. Participant profile

Procedure

Participants were recruited through the presentation of a recruitment flyer during KUCCD's teletherapy aphasia group therapy sessions. Interested individuals were contacted by the primary investigator to schedule a Zoom meeting.

After providing consent electronically via the Qualtrics platform, the participants initially completed a modified version of the Language Experience and Proficiency Questionnaire (LEAP-Q). The questionnaire provided researchers with information regarding the participants' language background. The Qualtrics questionnaire links were shared with the participants and completed with the researchers over Zoom. Researchers were involved in clarifying questions and providing explanations. Additionally, the four bilingual participants each had a family member present to aid in providing accurate

information throughout the questionnaire.

Upon completion of the questionnaire, the participants stayed in the Zoom meeting while completing the tasks. Each participant had the ability to perform the task independently without the researchers on Zoom, but they all selected to stay on to receive further explanation if necessary. Once both cognitive tasks were completed, the participants were debriefed on the study.

Measures/Materials

The LEAP-Q is typically used to assess a bilingual individual's language profile by asking questions related to language competence, acquisition, exposure, and use (Marian, Blumenfeld, & Kaushanskaya, 2007). The creators of the original LEAP-Q discovered that participants' self-reported responses were indicative of their performance in each language, suggesting the validity of the questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007). The researchers modified the questionnaire for relevance to the study; questions were omitted, altered, or added. Questions asked participants to explain their abilities in their language(s) before and after experiencing a stroke (See Appendix I for the complete questionnaire).

The questionnaire was created and posted on Qualtrics by the researchers. Qualtrics is a web-based survey platform that is used to conduct evaluations, survey research, and collect data from other sources. This simple online survey tool allows researchers to create their own surveys, send the surveys, and analyze the responses from the participants. In addition, Qualtrics is Health Insurance Portability and Accountability Act (HIPAA) compliant (Qualtrics, 2020). This allows participants to safely provide the researchers with identifying information in the survey contents.

The Stroop Color and Word Test (SCWT) is a neuropsychological test used to measure executive processing abilities, such as selective attention, cognitive flexibility and processing speed. More specifically, the SWCT assesses one's ability to inhibit cognitive interference when one stimulus obstructs the processing of a second stimulus simultaneously (Scarpina & Tahini, 2017). The SWCT has been extensively used for experimental purposes given its ability to quickly measure cognitive functions using three main tasks: Word task, Color task and Color-Word task. Researchers have frequently used the Word and Color task to assess speech motor function, while the Color-Word task component is believed to measure cognitive flexibility and interference control (Homack & Riccio, 2004).

To successfully complete the task, participants were required to have access to a laptop or computer with a mouse and keyboard. When completing the SCWT, the participants were presented with words written in the orthographic form in different color ink (e.g. "GREEN" printed in blue, "BLUE" printed in blue). The stimulus words and font color were categorized under two general conditions: congruent and incongruent trials (Pompon et al., 2015). In the congruent trial, the word and font color matched (e.g., "RED" printed in red). However, the word and font color were mismatched during the incongruent trials (e.g., "RED" printed in green). Stimuli were presented in bold 27-point Arial font at the center of a black background. Participants responded to each trial by identifying the color of the print using the following corresponding keys: "r" for red, "g" for green, "y" for yellow, and "b" for blue. Each participant completed the SCWT within 6 minutes.

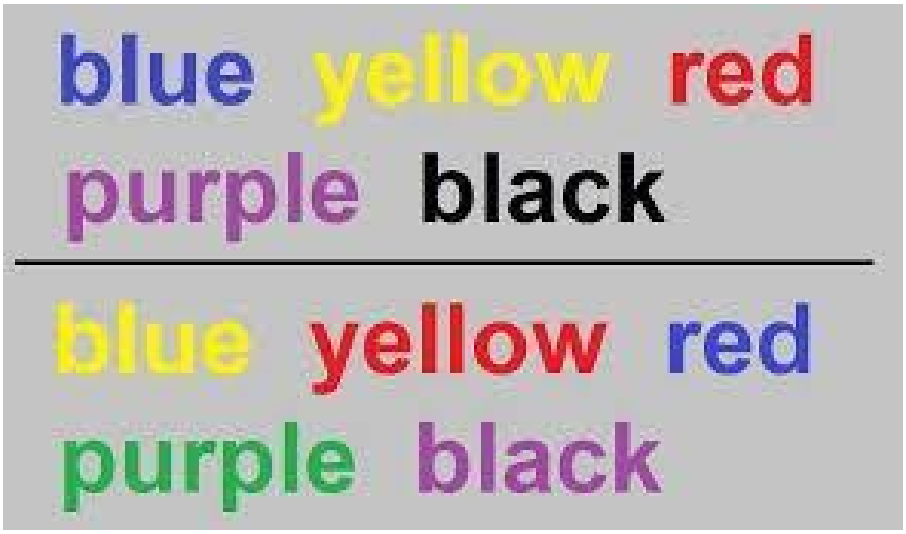


Figure 1. The Stroop Color and Word Test paradigm (Screenshot from T-Testing the Stroop Effect)

The Wisconsin Card Sorting Test (WCST) measures the executive functions of working memory, abstract thinking, cognitive flexibility, attention, set shifting, and perseverance. This neuropsychological test measures repeated behaviors that refer to an individual's perseverance in incorrect behavior (Coulacoglou & Saklofske, 2017). Researchers have used this test to measure impairments found in abstract reasoning and the ability to shift attention in response to an environmental change in individuals with neurological impairments. Fridriksson et al. (2005) examined executive function in individuals with aphasia by utilizing the WCST. Researchers have used the WCST to measure impairments found in abstract reasoning and the ability to shift attention in response to an environmental change in individuals with neurological impairments.

The WCST also requires all participants to use a laptop or computer with a mouse and keyboard. The task requires the participant to classify a presented card based on its color, form, or number of shapes. The participant will then be instructed to match the

initial card to another card based on one of the three criteria. For example, if the participant was presented with a card with one red triangle and was matching according to shape, they would select the other card with the triangle. If the participant was matching according to color, they would select the card with a red design. If the participant was matching according to number, they would select the card with one shape (see Figure 2). After several trials, the classification of sorting cards will automatically be altered by the program, and a new pattern will be selected. The participant will not be alerted of the change in pattern and will have to determine which one of the classifications is now being used. The duration of the WCST is 15 to 20 minutes long for the participant to complete.

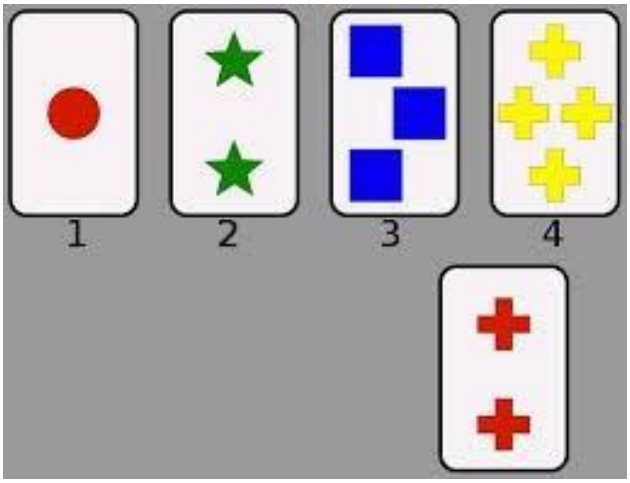


Figure 2. The Wisconsin Card Sorting Task (Screenshot taken from Wikipedia)

Both of the cognitive tasks involved in the study were hosted on PsyToolkit. Originally, PsyToolkit was created as software for Linux to allow students and researchers to modify and perform a variety of psychology experiments, ranging in difficulty, free of charge (Stoet, 2010). The website was then created for greater accessibility to researchers. Creators are able to use or modify existing questionnaires and experiments to distribute to

participants as a survey (Stoet, 2016). The survey does not gather personal information and assigns each user a randomized code number. Once participants complete the task, their results add to a file of all data for the task, which the researchers are able to compile into a data file to analyze independently.

Results

Modified LEAP-Q

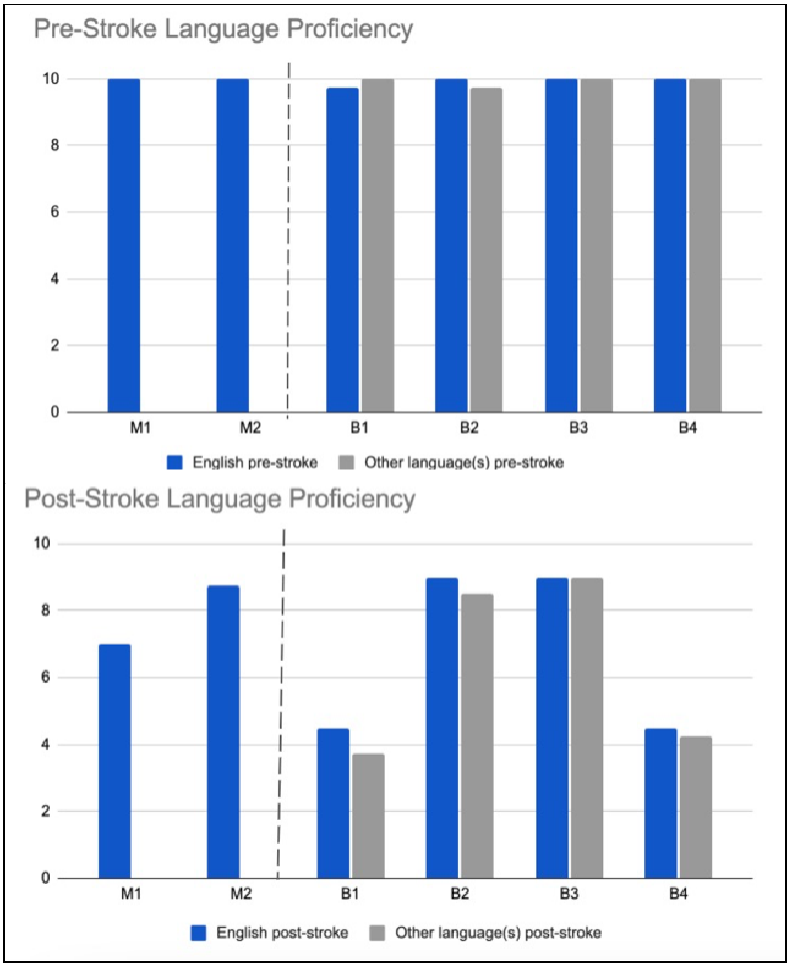
All participants completed the language profile questionnaire. Results from the Likert Scale and selected response questions were analyzed to determine each participant's language proficiency before and after experiencing a stroke. Both monolingual and bilingual groups rated their language proficiency on a Likert Scale across the domains of reading, writing, speaking, and understanding before and after their strokes. When rating their pre-stroke abilities, the bilingual group provided the following responses: B1 rated the other language higher than English; B2 rated English higher than their other language; B3 and B4 both rated English and their other language equally. When rating their post-stroke abilities, the bilingual group provided the following responses: B1, B2, and B4 rated English higher than their other language; B3 rated English and their other language equally. When rating their overall post-stroke language proficiency across both languages, all participants across both groups rated themselves lower than their pre-stroke language abilities.

Findings from the LEAP-Q indicated that three out of four participants in the bilingual group identified as being sequential language learners. Sequential language learners are described as learning their primary language first and acquiring the second

language after the age of three (e.g., preteen or adolescent years). The remaining participant from the bilingual group was a simultaneous language learner, meaning they were exposed to two languages since birth and acquired both languages simultaneously.

When disaggregating the LEAP-Q data by language preference per setting, three of the four bilingual participants responded that they typically use their primary language (i.e., Spanish and Mandarin Chinese) in their activities of daily living. This comprises more informal settings, including their home and during large family gatherings. The English language was predominantly used in formal settings, such as school and work. The fourth bilingual participant identified using primarily English in both informal and formal settings.

Figure 3. Pre-Stroke and Post-Stroke Language Proficiencies



Stroop Color and Word Test

Although all participants attempted the Stroop Color and Word Test, not all participants were able to complete the task. Three bilingual participants attempted the task and abandoned it before completion. Both the monolingual participants and one bilingual participant were able to complete the task. However, accuracy rates were quite low. The individuals who completed the Stroop Test provided between 1 to 5 correct responses across 40 trials.

Table 2. Results from Stroop Color and Word Test

Participant	Trials attempted	Trials correct	Congruent/Incongruent (for Correct Trials only)
M1	5	5	3 Congruent / 2 Incongruent
M2	2	1	0 Congruent / 2 Incongruent
B3	7	2	1 Congruent / 1 Incongruent

Wisconsin Card Sorting Task

All participants were able to complete the Wisconsin Card Sorting Task. When considering total errors, on average, the monolingual group experienced fewer errors than the bilingual group, with each group's errors being 46.68% and 50.11%, respectively. On average, the monolingual group experienced incorrect perseverations on 15.02% of trials, while the bilingual group experienced incorrect perseverations on 17.52% of trials. Additionally, the monolingual group had a faster reaction time on correct trials, with a time of 3562.68ms compared to the bilingual group's reaction time of 6148.66ms.

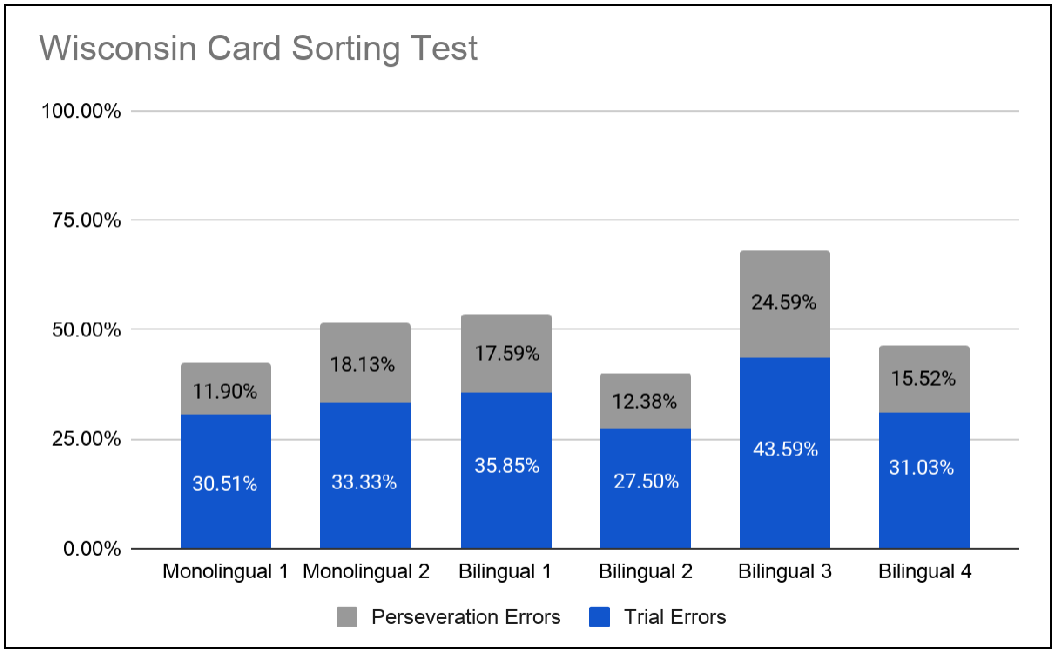


Figure 4. Results from Wisconsin Card Sorting Test

Aphasic Participant Group	Mean % of Trial Errors
Monolingual	46.68%
Bilingual	50.11%

Table 3. Mean Percentage of Trial Errors of the WCST

Aphasic Participant Group	Mean % of Perseveration Errors
Monolingual	15.02%
Bilingual	17.52%

Table 4. Mean Percentage of Perseveration Errors of the WCST

Aphasic Participant Group	Mean Response Times of Correct Trials (ms)
Monolingual	3562.86
Bilingual	6148.66

Table 5. Mean Response Times of Correct Trials in milliseconds of the WCST

Participant	Correct Trials / Total Trials Attempted	% of Correct Trials
M1	36/59	61%
M2	26/57	45%
B1	27/53	50%
B2	17/39	44%
B3	29/58	50%
B4	22/40	55%

Table 6. Results for all participants of the WCST

Overall, on average, the monolingual group attempted more trials compared to the bilingual group. Within the bilingual group, participant B2 and participant B4 provided a response for 66% of all trials presented, whereas participant B1 and participant B3 provided a response for at least 88% of all trials presented. Participant M1 completed the most trials and scored the highest in total accuracy percentage of correct trials attempted. All other participants were within the 44% to 55% accuracy range, regardless of their language status.

Discussion

This study aimed to examine the cognitive-linguistic abilities of bilingual and monolingual individuals within the aphasia community. Specifically, the researchers

sought to determine if bilingual individuals experience more efficient executive functioning, especially in the areas of cognitive flexibility and inhibition control.

Based on our findings of the WCST, the monolingual aphasic group exhibited fewer trial errors on average (46.68%) compared to the bilingual aphasic group (50.11%). On average, the bilingual aphasic group also demonstrated higher preservation errors (17.52%) than the monolingual aphasic group (15.02%). The results indicate that the bilingual group displayed more difficulty in inhibitory control compared to the monolingual group, as demonstrated by their higher rate of perseverative errors. In terms of overall speed when completing the task, the bilingual group's mean response time (6148.66 ms) was double the mean response time of the monolingual group (3562.86 ms). The monolingual aphasic group displayed faster mean response times on all correct trials when selecting stimuli. Although reaction time is not an executive functioning skill in and of itself, processing speed can impact mental flexibility and inhibitory control. Therefore, the bilingual aphasic group did not demonstrate the bilingual advantage.

The WCST was used to determine an individual's mental flexibility and cognitive ability. It was hypothesized that the bilingual advantage would lead to bilingual individuals experiencing faster reaction times, thus displaying stronger cognitive flexibility. However, data results show that the monolingual group experienced faster reaction times, suggesting that those individuals have higher cognitive flexibility. Previous research regarding the bilingual advantage has also found higher executive functioning skills in the monolingual groups in both typically healthy populations (Dick et al., 2019) and in aphasia patients (Faroqi-Shah et al., 2016).

Based on the results of the modified LEAP-Q questionnaire, it was concluded that

aphasia patients rate their average language proficiency lower after experiencing a stroke, regardless of their language status (bilingual or monolingual).

Limitations

There are several limitations to this study. Researchers were only able to recruit 6 participants for the study, leading to difficulty in generalizing results. The number of participants in each group was also unbalanced, as there were only two monolingual participants and four bilingual participants, which further limits generalizability.

The language profile questionnaire relied on self-reports from the participants and may not accurately reflect their language abilities. Additionally, computerized errors prevented participants' responses to certain questions from being correctly recorded after their questionnaires were submitted.

The tasks used for the study were computerized and pre-existing; therefore researchers were not physically able to demonstrate the tasks and aid the participants. Also, the settings for the Stroop task may not have allowed the participants enough time to answer, resulting in the high error rates (mostly due to non-response trials rather than incorrect response trials) and the high number of participants who could not complete the task. Limitations in the participants' ability to complete this test could also be due to fine motor weaknesses as a result of hemiparesis. Participants were not able to reach floor which resulted in inconclusive data analysis.

Future Research

It is recommended that future research regarding this population should include balanced groups of monolingual and bilingual participants. Future researchers would

benefit from a larger sample size more representative of the monolingual and bilingual aphasia populations to further support or refute the bilingual advantage.

Additionally, it would be beneficial to administer the assessments with the participants rather than independently via pre-existing tasks to best accommodate each participant's abilities. For the bilingual participants, it is unclear whether or not their caregivers were guiding the mouse or selecting the correct keys during trials, which would skew the results. Completing the cognitive tasks in person with the researchers would ensure the participants are completing the tasks independently.

The cognitive status of the participants were undisclosed to the researchers. For example, several participants may have additional deficits such as right side hemiparesis, left neglect, etc. Future researchers should consider including information about additional deficits of the participants.

This line of research has the potential to provide future directions in the field of bilingualism and aphasia. Further, since executive functioning skills play an important role for rehabilitation, as it supports functional independence and social integration (Ana et al., 2018), findings of this research could elucidate potential areas of therapeutic interventions for bilingual individuals with aphasia and cognitive impairments.

References

Ana, P.B., Mello, C., Pereira, A.H., Ferre, P., Fonseca, R.P., & Joanette, Y. (2018). Executive functions assessment in patients with language impairment: a systematic review. *Dementia and Neuropsychologia, 12(3)*, 272-283.

Ansaldo, A. I., & Saidi, L. G. (2014). Aphasia Therapy in the Age of Globalization: Cross-Linguistic Therapy Effects in Bilingual Aphasia. *Behavioural Neurology, 1–10.* doi:10.1155/2014/603085

Aphasia (2017, March 6). *National Institute on Deafness and Other Communication Disorders.* Retrieved October 26, 2020 from https://www.nidcd.nih.gov/health/aphasia

Bialystok, E., Craik, F. I. M., & Freedman, M. (2007). Bilingualism as a protection against the onset of symptoms of dementia. *Neuropsychologia, 45(2),* 459–464. doi:10.1016/j.neuropsychologia.2006.10.009

Bialystok, E., Craik, F., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(4), 859–873. https://doi.org/10.1037/0278-7393.34.4.859

Chertkow, H., Whitehead, V., Phillips, N., Wolfson, C., Atherton, J., & Bergman, H. (2010). Multilingualism (But Not Always Bilingualism) Delays the Onset of Alzheimer Disease: Evidence From a Bilingual Community. Alzheimer Disease & Associated Disorders, 24(2), 118-125. doi:10.1097/wad.0b013e3181ca1221

Dekhtyar, M., Kiran, S., & Gray, T. (2020). Is bilingualism protective for adults with aphasia? *Neuropsychologia, 139.* doi:10.1016/j.neuropsycholgia.2020.107355

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64,* 135–168. doi:10.1146/annurev-psych-113011-143750.

Dick, A. S., Garcia, N. L., Pruden, S. M., Thompson, W. K., Hawes, S. W., Sutherland, M. T., . . .
Gonzalez, R. (2019). No evidence for a bilingual executive function advantage in the ABCD study. *Nature Human Behaviour, 3*(7), 692-701. doi:10.1038/s41562-019-0609-3

Faroqi-Shah, Y., Sampson, M., Pranger, M., & Baughman, S. (2016). Cognitive control, word retrieval and bilingual aphasia: Is there a relationship? *Journal of Neurolinguistics,* 1-15. doi:10.1016/j.jneuroling.2016.07.001

Fridriksson J, Nettles C, Davis M, Morrow L, & Montgomery A. (2006). Functional communication and executive function in aphasia. Clinical Linguistics & Phonetics, 20(6), 401–410.https://doiorg.kean.idm.oclc.org/10.1080/02699200500075781

Goncalves, A., Mello, C. Periera, A., Ferre, P., Fonseca, R. & Joanette, Y. (2018). Executive functions assessment in patients with language impairment: a systematic review. *Dementia Neuropsychology*, 12(3), 272-283. doi: 10.1590/1980-57642018dn12-030008

Hope, T. M., Jones, ‘ P., Grogan, A., Crinion, J., Rae, J., Ruffle, L., . . . Green, D. W. (2015). Comparing language outcomes in monolingual and bilingual stroke patients. *Brain, 138*(4), 1070-1083. doi:10.1093/brain/awv020

Kousaie, S., Shepphard, C., Lemieux, M., Monetta, L., & Taler, V. (2014). Executive function and bilingualism in young and older adults. Frontiers in Behavioral Neuroscience, 8. doi:10.3389/fnbeh.2014.00250

Lahiri, D., Ardila, A., Dubey, S., Mukherjee, A., Chatterjee, K., & Ray, B. K. (2020). Effect of bilingualism on aphasia recovery. *Aphasiology,* 1-22. doi:10.1080/02687038.2020.1812032

Penn, C., Frankel, T., Watermeyer, J., & Russell, N. (2010). Executive function and conversational strategies in bilingual aphasia. *Aphasiology, 24(2),* 288-308.

Poarch, G.J. & Krott, A. (2019). A Bilingual Advantage? An Appeal for a Change in Perspective and Recommendations for Future Research. *Behavioral Sciences, 9(9),* 1-13.

Purdy, M. (2002). Executive function ability in persons with aphasia. *Aphasiology, 16(4/6*), 549–557

Secer, I. (2016). Skills of cognitive flexibility in monolingual and bilingual younger adults. *The Journal of General Psychology, 143(3),* 172-184.

doi:10.1080/00221309.2016.1200530

Van den Noort, M., Struys, E., Bosch, P., Jaswetz, L., Perriard, B., Yeo, S., . . . Lim, S. (2019).
Does the Bilingual Advantage in Cognitive Control Exist and If So, What Are Its Modulating Factors? A Systematic Review. *Behavioral Sciences, 9*(3), 27. doi:10.3390/bs9030027

Appendix I: Participant Questionnaire Participant Questionnaire

Background/Participant Information:

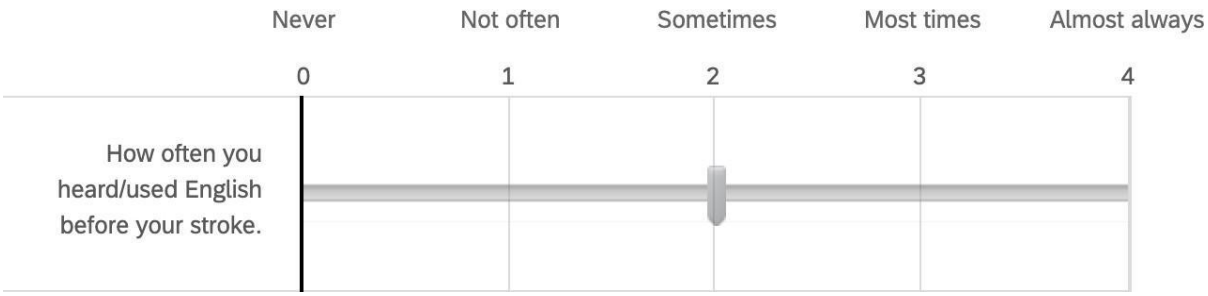
1) Date of birth. (fill in)
2) What type of aphasia do you have? (fill in)
3) What year were you diagnosed with aphasia? (fill in)
4) Please list all of the languages you know. (fill in)
5) Please list the languages you know in the order that you learned them. (fill in)
6) Please choose your highest level of education. (check box)

Less than high school	Some college	Masters
High school	College	PhD/MD/JD
Professional training	Some graduate school	Other

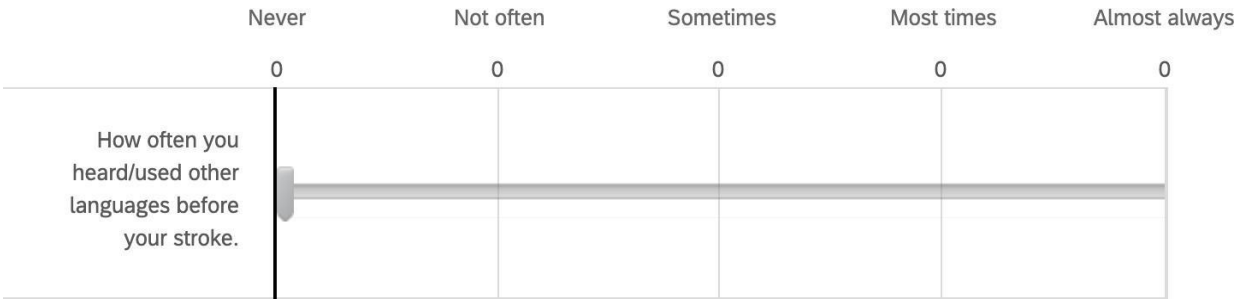
7) If applicable, please provide the year you moved to the United States of America. (fill in)
8) Have you ever had a vision problem? (yes/no)
9) Have you ever had a hearing problem? (yes/no)
10) Did you have a language issue pre-stroke? (yes/no)

Before your stroke:

11) Please select how often you heard or used English. (scale from never, not often, sometimes, most times, almost always)



12) Please select how often you heard or used other languages (if applicable). (scale from never, not often, sometimes, most times, almost always)



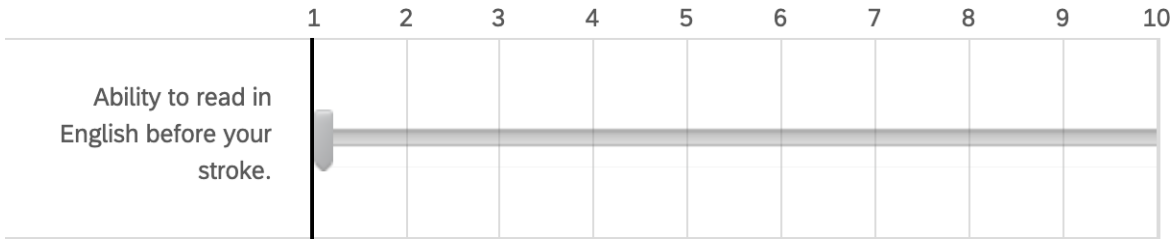
13) Please write the age when you learned English. (fill in)

14) Please write the age when you learned your other languages (if applicable). (fill in)

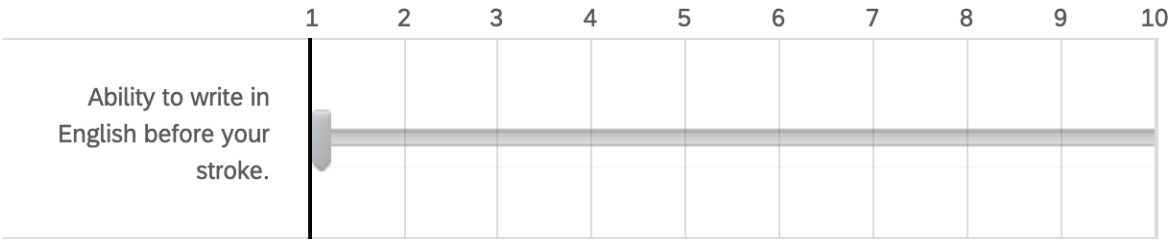
15) In general, what language did you use the most in each place before your stroke. (select English or other languages for each option)

	Which language did you use more?	
	English	Other Language
At home	○	○
At work	○	○
With friends	○	○
At the grocery store	○	○
At school	○	○
Large family gatherings	○	○

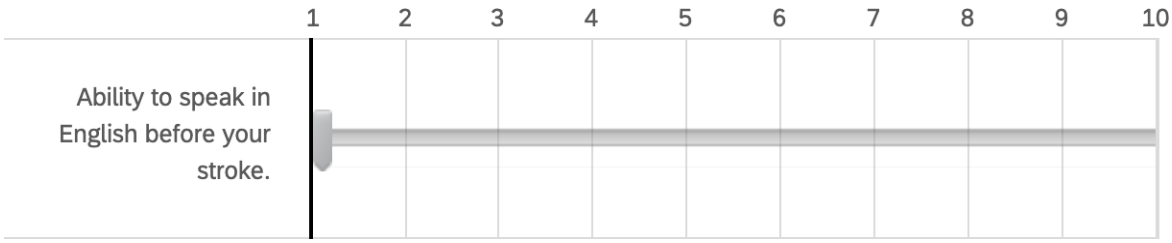
16) Please rate your ability to read in English pre-stroke. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



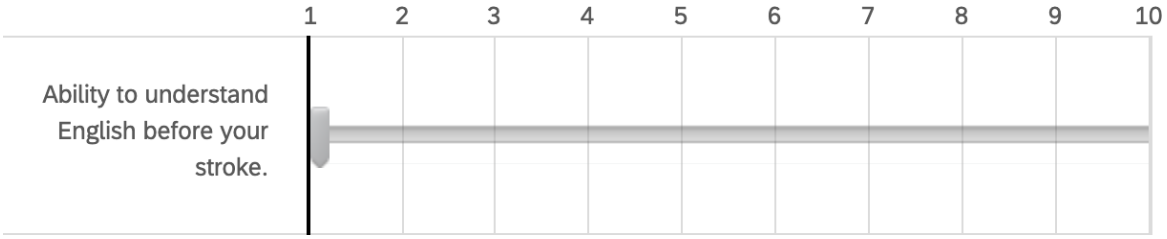
17) Please rate your ability to write in English pre-stroke. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



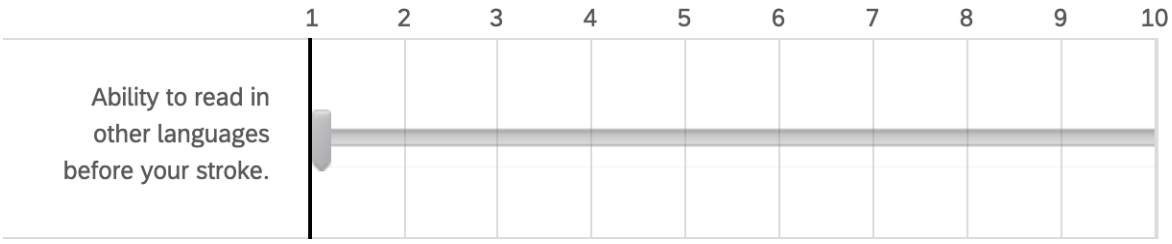
18) Please rate your ability to speak English pre-stroke. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



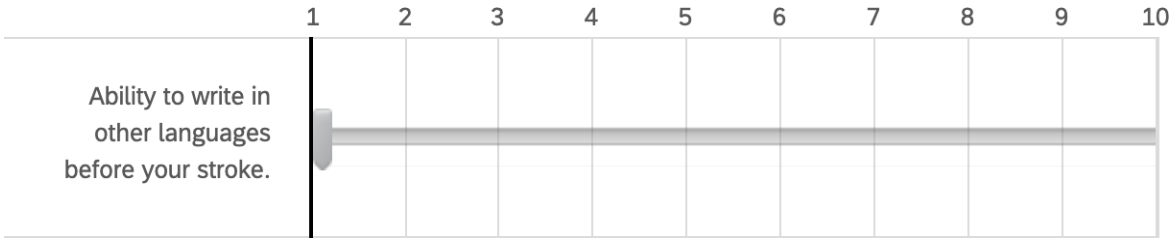
19) Please rate your ability to understand English pre-stroke. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



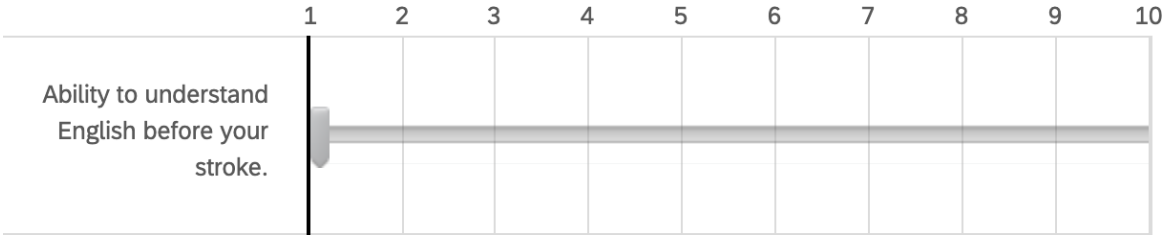
20) Please rate your ability to read in your other languages pre-stroke (if applicable). Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



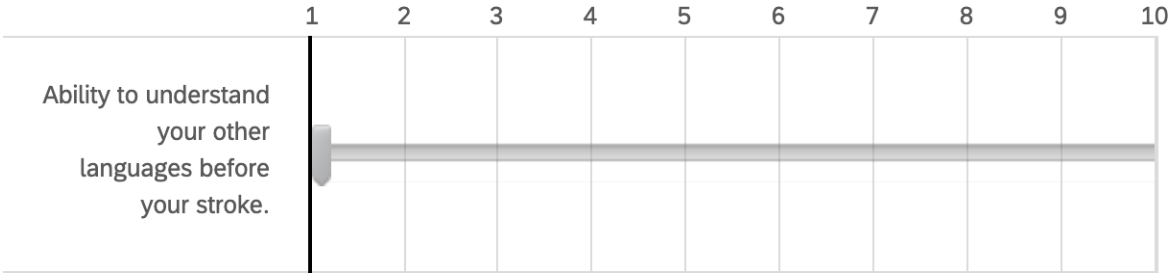
21) Please rate your ability to write in your other languages pre-stroke (if applicable). Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



22) Please rate your ability to speak in your other languages pre-stroke (if applicable). Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



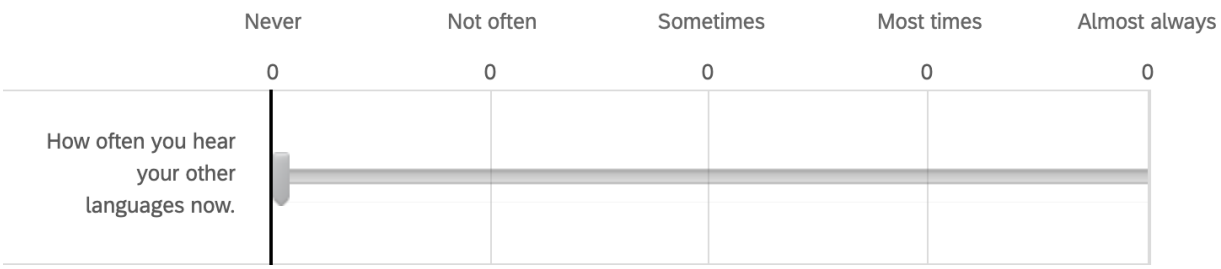
23) Please rate your ability to understand your other languages pre-stroke. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



After the stroke:

24) Please select how often you hear or use English. (Scale from never, not often, sometimes, most times, almost always).

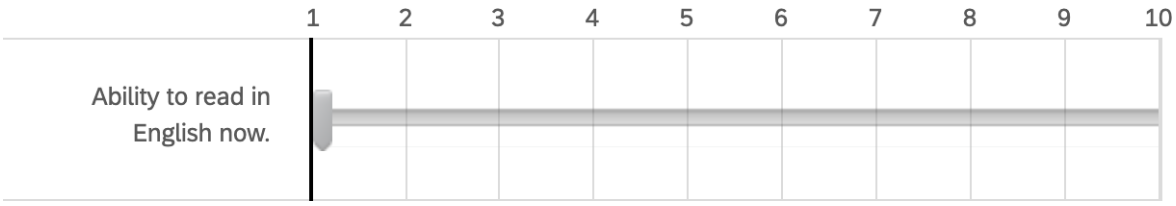
25) Please select how often you hear or use other languages (if applicable) (Scale from never, not often, sometimes, most times, almost always).



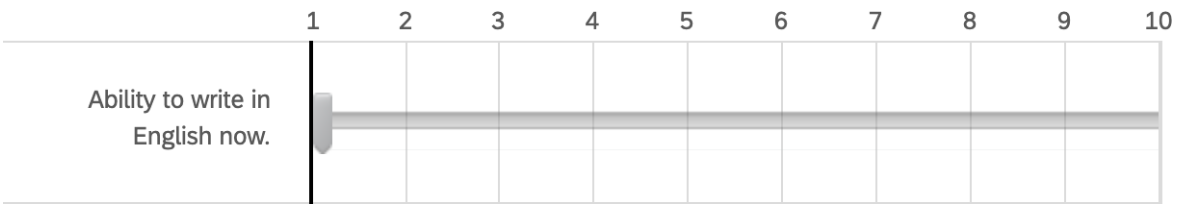
26) In general, what language do you use the most in each place after your stroke. (select English or other languages)

	Which language do you use most?	
	English	Other
At home	○	○
At work	○	○
With friends	○	○
At the grocery store	○	○
At school	○	○
Large family gatherings	○	○

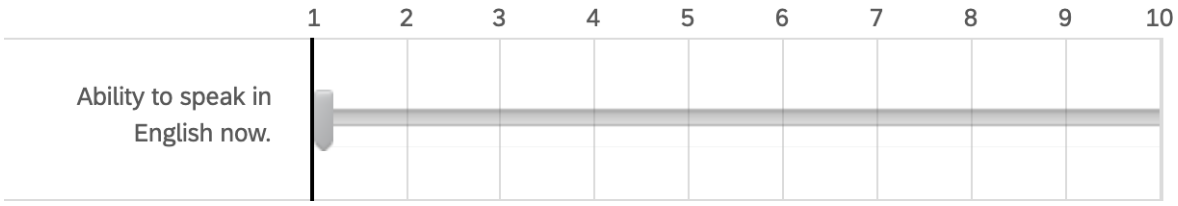
27) Please rate your ability to read in English now. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



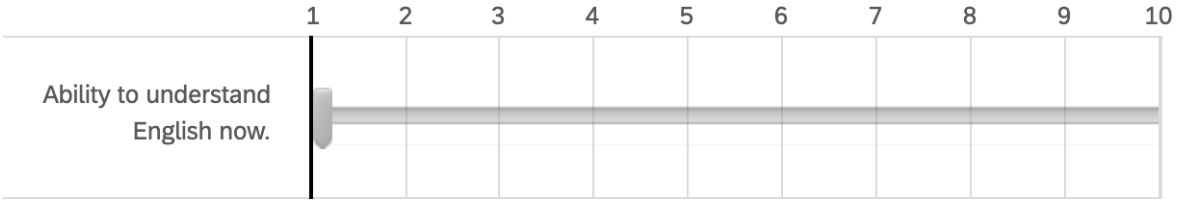
28) Please rate your ability to write in English now. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



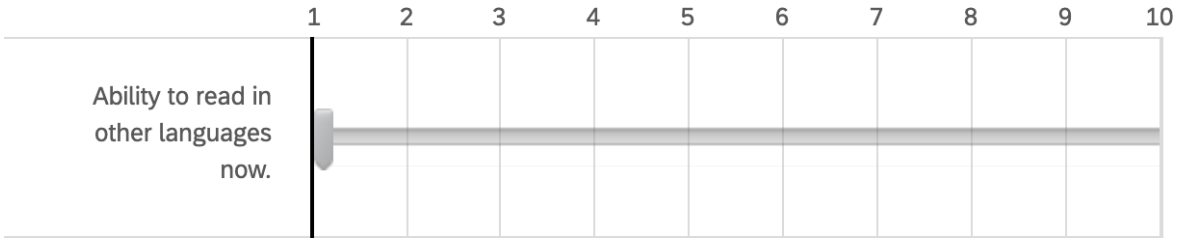
29) Please rate your ability to speak in English now. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



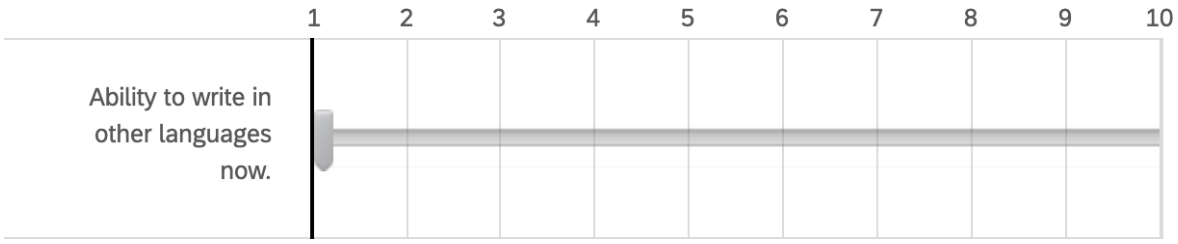
30) Please rate your ability to understand English now. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



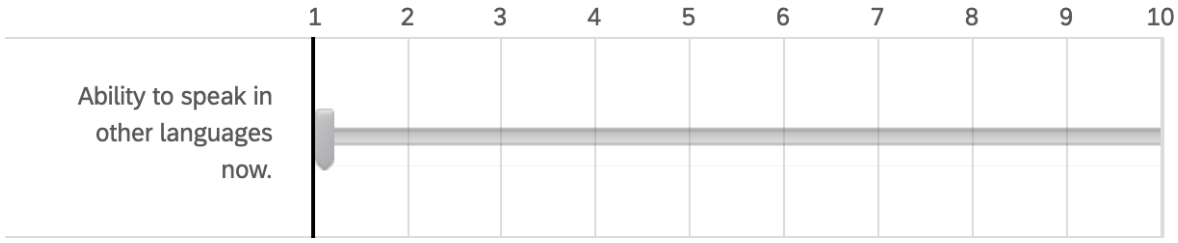
31) Please rate your ability to read in your other languages now. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



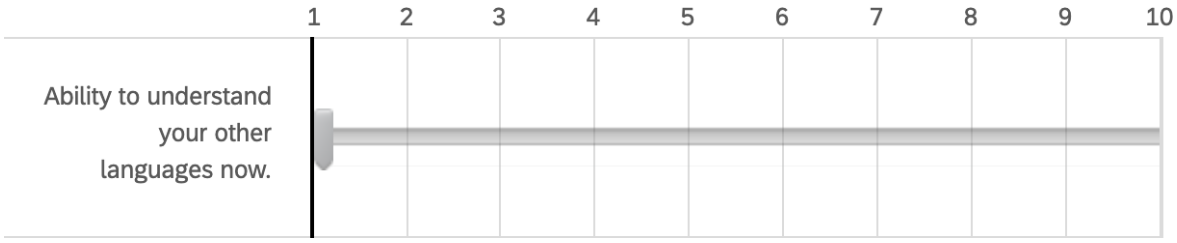
32) Please rate your ability to write in your other languages now. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



33) Please rate your ability of speaking in your other languages now. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



34) Please rate your ability to understand your other languages now. Rate 1 - 10, 1 being the lowest and 10 the highest. (e.g. low, adequate, native)



Appendix II: Informed Consent Form

KEAN

Informed Consent Form

Title of Study: Assessing Cognitive Function of Bilingual and Monolingual Aphasia Patients

Primary Researcher(s): Alexa Juarez (juarezal@kean.edu), Caroline Kerrigan (kcarolin@kean.edu), Natasha Patel (patnatas@kean.edu)
Department of Communication Disorders and Deafness

Faculty Advisor: Jessica Scheuer, M.S., CCC-SLP

Nathan Weiss Graduate College, Department of Communication Disorders and Deafness
Contact information: scheujes@kean.edu

Invitation to Participate:

You are invited to be in a research study assessing the executive functioning skills of individuals with aphasia who are bilingual and monolingual.

Purpose of Study:

This study aims to assess the executive functioning skills of individuals with aphasia who are bilingual and monolingual and compare their results to determine if there is a difference in performance. Specifically, our hypothesis would test cognitive flexibility amongst bilingual aphasic and monolingual aphasic patients. Previous research regarding cognitive abilities has found that bilingual people may be at an advantage compared to monolingual populations due to increased interference/inhibition abilities when performing tasks. The researchers of this study hypothesize that bilingual aphasia patients will have better performance results on two cognitive tasks, the Stroop Task and the Wisconsin Card Sorting Task.

Participation Selection:

This study is intended for adults who have been diagnosed with aphasia secondary to a cerebrovascular accident who are monolingual (i.e. speaks one language fluently) or bilingual/multilingual (i.e. speaks two or more languages proficiently).

Procedures:

If you agree to participate in this study, you will answer a questionnaire about your language profile and complete two computer-based cognitive tasks online. Instructions regarding how to access and operate the online tasks will be explained to all participants during an initial online information session, before commencing the study. All activities can take place while you are at your home. You should be

prepared to spend about 20 minutes in front of the computer to complete each of the tasks (approximately 60 minutes total). You will be able to take breaks intermittently throughout the session or complete the activities on separate days.

Your participation will take approximately 45 to 60 minutes.

Potential Risks:

Participants should be aware that there is a risk of breach of anonymity. The responses to the questionnaire and online tasks will not be anonymous to the researchers and the faculty advisor, but participants will use an assigned code for the questionnaire and tasks so that they cannot be readily identified by others. Additionally, your answers will be downloaded as soon as you complete the project then deleted from their respective sites. Other possible risks involved in this research study may include mild frustration and a loss of self-esteem. This type of stress could be due to the time commitment that is required for the research study. This will be reduced by scheduling home-based testing sessions at your convenience and allowing for breaks throughout testing. Additionally, participants may feel a loss of self-esteem if they think that they are under performing throughout the tasks. Please contact the Kean University Psychological Services at (908) 737-5890 to address any kind of negative emotions you may feel as a result of study activities.

Potential Benefits:

No direct benefits are expected to result from this study. This study serves to benefit the field of speech-language pathology. Results of this study may aid in developing treatment for bilingual individuals with aphasia.

Financial Obligation:

The participant will not be subject to any financial obligation for the purposes of this study.

Compensation:

Participation in this research is completely voluntary. There is no compensation associated with this study.

Confidentiality:

All participation will be kept confidential. All testing results and data will be stored in a safe and guarded environment. Records will be stored in locked file cabinets for five years. Computerized files will be kept on a password protected drive, locked in a file cabinet when not in use. All computerized data files and paper records will not contain any identifying participant information. After five years, the records will be shredded and files will be deleted. Any and all conversations between you and the researcher that take place during the study will be treated as private, and thus will not be shared with anyone other than the researchers. Any published material will not contain any information that will make it possible to identify you as a subject.

Participant/Withdrawal Statement:

Participation in this study is voluntary. You have the right to decide not to participate. You may choose

to stop participating at any point. If you decide to stop participating, your results will be withdrawn and you will not be penalized.

Questions/Comments:

Should participants have any questions or concerns, they may reach out to Alexa Juarez and the research team, or their faculty advisor, Jessica Scheuer. If there are questions regarding individual rights as research participants, the contact information for the IRB can be found below.

Primary investigator/Graduate student: Alexa Juarez, juarezal@kean.edu

Faculty Advisor: Jessica Scheuer, MS, CCC-SLP- scheujes@kean.edu or (908) 737-5801.

IRB: (908) 737-3461 or IRB@kean.edu

Agreement to Participate:

If you agree to participate in this study, please select the corresponding box designated below. Your electronic signature indicates that you have read and understood the information provided in this document, and that you agree to participate in this study. If at any time you have questions regarding this study, please contact the primary investigator or faculty advisor at the email address provided in this document.

By selecting the button below, you acknowledge that your participation in this study is voluntary, you are 18 years of age or older, and that you are aware that you may choose to withdraw your participation in the study at any time and for any reason.

Appendix III: Debriefing Form

KEAN

Nathan Weiss Graduate College | Kean University

Debriefing Form Guidelines

Title of the Project:

Assessing Cognitive Function of Bilingual and Monolingual Aphasia Patients

Principal Investigators:

Alexa Juarez
Email: juarezal@kean.edu

Natasha Patel
Email: patnatas@kean.edu

Caroline Kerrigan
Email: kcarolin@kean.edu

Faculty Advisor:

Jessica Scheuer, M.S., CCC-SLP
Email: scheujes@kean.edu

Thank you for participating as a research participant in the present study concerning the cognitive skills of monolingual and bilingual individuals with aphasia. We appreciate your time and willingness to participate in the study. The information we gathered from your results will make a valuable contribution to our knowledge about bilingual individuals with aphasia.

Aphasia, an acquired language disorder resulting from a brain injury, currently affects about 1 million people in the United States (ASHA, n.d.). The leading cause of aphasia is a stroke, leaving 25 to 40 percent of survivors with an expressive and/or receptive disorder that can affect one or more of the four language modalities: spoken language expression, spoken language comprehension, written expression, and reading comprehension (ASHA, n.d.). In addition to linguistic deficits, individuals with aphasia may also present with impairments in executive function and cognitive control.

Previous research has uncovered that bilingual individuals may display increased cognitive ability for specific executive functions when compared to monolingual populations. When

completing a Stroop Task, similar to the one you have just completed, bilingual adults have had a faster reaction time compared to monolingual adults, indicating that they may display increased interference control (Bialystok, Craik, & Luk, 2008). Researchers discovered similar findings of lower reaction time in bilingual adults with aphasia when they completed cognitive tasks (Dekhtyar, Kiran, & Gray, 2020). The researchers determined that cognitive advantages in the bilingual group were due to the number of languages spoken because the groups were matched and controlled for all other factors. However, another research study has also found that bilingual groups with aphasia did not have a decreased reaction time on cognitive tasks, suggesting that there is not a bilingual advantage (Faroqi-Shah, 2018). This study aims to assess the executive functioning skills of individuals with aphasia who are bilingual and monolingual to determine if there is a difference in abilities between the two groups.

Your Right to Withdraw Data

After completing the tasks, you may want to have your data removed from the study. If you decide to have your data withdrawn, please contact one of the principal investigators of this study. Your responses and results will be removed from our records. There will be no consequences or penalties for you if you decide to remove your data from the study. Before finalizing your decision, please ask the researchers of this study any questions that you have.

If You Have Any Questions or Concerns

If you have any questions or concerns about this study and the research procedures used, you may contact Alexa Juarez at juarezal@kean.edu, and our Kean University faculty supervisor, Jessica Scheuer at scheujes@kean.edu. If you have any questions regarding your rights as a research participant in this study, you may contact the Kean Institutional Review Board (IRB) to speak to someone independent of the research team at (908)-737-3461 or email at IRB@kean.edu. If you are feeling any kind of negative emotions or stress as a result of any part of this research study, feel free to contact the Kean University Psychological Services at (908) 737-5890.

If you would like further information on the topic, you can consult the following resources:

Bialystok, E., Craik, F., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(4), 859–873. https://doi.org/10.1037/0278-7393.34.4.859

Dekhtyar, M., Kiran, S., & Gray, T. (2020). Is bilingualism protective for adults with aphasia? *Neuropsychologia, 139.* doi:10.1016/j.neuropsycholgia.2020.107355

Faroqi-Shah, Y., Sampson, M., Pranger, M., & Baughman, S. (2018). Cognitive control, word retrieval and bilingual aphasia: Is there a relationship? *Journal of Neurolinguistics, 45*, 95-109. doi:10.1016/j.jneuroling.2016.07.001

https://www.newyorker.com/science/maria-konnikova/bilingual-advantage-aging-brain

Thank you for participating!