International Journal of Psychological Studies; Vol. 15, No. 2; 2023
ISSN 1918-7211 E-ISSN 1918-722X
Published by Canadian Center of Science and Education

The Difference between Monolingual and Bilingual Stutterers: A Systematic Review

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Received: April 14, 2023 Accepted: May 11, 2023 Online Published: May 19, 2023

doi:10.5539/ijps.v15n2p41 URL: https://doi.org/10.5539/ijps.v15n2p41

Abstract

The article is a comprehensive review regarding group differences of brain structures, cognitive process, and emotional responses between monolingual people who stutter (MWS) and bilingual people who stutter (BWS). Until now, researchers have been examining MWS and BWS separately, yet the compare between these two groups of people is lacking. In this work, the overview of MWS and BWS are introduced, different types and traits of stutter between MWS and BWS are compared, and the differences between brain structure, executive force, motor control, and cognitive reserve are investigated and synthesized based on previous studies. Both MWS and BWS have executive deficits in speech motor control, while BWS seem to be classified as having greater potential in language inhibitory and switching, thus transferring to general executive control. The conclusions are that BWS generally experience increased neural connectivity due to larger volume of grey and white matter than MWS, and thus gaining cognitive control abilities. Further research is warranted for the bilingual advantage and the exact etiology for stuttering.

Keywords: stuttering, difference, bilinguals, monolinguals, brain structures, broca's area, neural reserve, cognitive processing, executive functions, emotional responses, anxiety

1. Introduction

1.1 Basic Concepts

Stuttering is a speech disorder where the flow of speech is disrupted by repetitions (e.g. st-st-stutter), blocks (e.g. no sound produced), and prolongations (e.g. s-s-s-stutter) of sounds, syllables, words, or phrases involuntarily. A person who stutters is unable to produce sounds without blocks or silent pauses, and it prevails in every region of the world. Stuttering disfluency vary in quality: common disfluency tend to be repeated movements, fixed postures, or superfluous behaviors. Each of these three categories is composed of subgroups of stutters and disfluency. Repeated movements include syllable repetition (e.g. "on—on—on a chair"), incomplete syllable repetition (e.g. "c—c—c—cold"), and multi-syllable repetition (e.g. "I know—I know—I know a lot of information") (Teesson et al., 2003). The etiology of stuttering is yet unknown, but previous studies have found different gene arrangement and brain dysfunction between people who stutter (PWS) and people with no stutter (PWNS). A study by Foundas et al. (2001) provides strong evidence that adults with persistent developmental stuttering have anomalous anatomy in perisylvian speech and language areas by comparing the MRI scans of people with developmental stuttering and people who don't; however, except for the one anatomic feature that distinguished the groups of adults with no developmental stuttering and their counterparts, multiple loci (the position of a gene or chromosome) are responsible for stuttering. Anatomic anomalies within perisylvian speech–language areas may contribute to further development of stuttering.

Bilingualism is the use of more than one language, and its speakers outnumber its opponent, monolinguals (people who speak only their native language), in the world population. Multilingualism is the use of more than one language by individuals or groups, and bilingualism is included. In this review, bilingualism is limited to stutterers who speak two different languages, and monolingual is limited to stutterers who speak a single language. Language learning is a cognitive process, where the second language is processed either simultaneously with their first language, or sequentially after the first language was acquired. In simultaneous bilingualism, people developed two languages at a young age due to their bilingual growing environment in a natural setting, and are proficient in the two languages without learning through translation later on. In sequential acquisition, children or

adult learn the second language in a tutored environment. The phase of second language acquisition among children vary greatly, which is a more complex and lengthy process, although there is no indication that children with typical language development end up less proficient than simultaneous bilinguals, as long as they receive adequate input in both languages (Gass et al., 2008). Early bilingualism includes infant bilingualism, which is roughly up to the age of three, and child bilingualism, which is approximately to the age of puberty. Late bilingualism is becoming a bilingual speaker after growing into adults. Receptive bilinguals are those who can understand a second language but who cannot speak it or whose abilities to speak it are inhibited by psychological barriers, which are not included in this discussion.

In language acquisition, infants start to produce their first word (e.g., "mama" or "papa") around one year old. Children typically start stuttering at the age between 2 and 4 when they first start to string together words to create longer sentences instead of simply producing a few syllables or phonemes. Some children don't stutter until later in their childhood, and it is important to be assessed as early as possible if the sign of stuttering occurs. Stuttering may result in nonverbal body gestures including blinking their eyes, grimacing, tensing their face or clenching their fists, which are ways in which infants may compensate for their language disfluency.

1.2 Research Method

Based on credible published journals on sources including Google Scholar, Wikipedia, and Pubmed, a few long-standing causes of stuttering are listed below. Also called stammering or childhood-onset fluency disorder, there are multiple hypotheses and theories that contribute to stuttering. Stuttering, usually inborn, is predominantly caused by genetics, and children who have first-degree relatives who stutter are three times as likely to develop a stutter, while environmental factors will interact for stuttering to occur. Family history of the disorder doesn't necessarily lead to stuttering. Stressful stimuli from the outside environments are unlikely to cause constant and inalterable stuttering. The existence of a more active male hypothalamic-pituitary-adrenal (HPA) leads to more boys stuttering than girls, in the ratio of 3 to4 boys:1 girl. Males produce more cortisol than females under the same provocation and they can be tense or anxious and become more severe in stuttering (Leisman et al., 2022). Congenital factors play a role in some people who stutter. In past studies, researchers estimated that alteration of three genes GNPTAB, GNPTG, and NAGPA, were present in 9% of those who have a family history of stuttering (Gunasekaran et al., 2021). It is not yet clearly known whether the differences in brain structures of stutterers is the consequence or the cause, but recent research on older children confirms structural differences that don't appear in younger children, thereby giving strength to the argument that at least some of the differences are not a consequence of stuttering (Watkins et al., 2008).

1.3 Purpose

Stutterers comprise one percent of the world population, yet previous studies show that stuttering lacks appropriate, reasonable public cognition deserved. Available measures and assessment instruments in this domain are scarce. Emotional barriers and anxiety present in stutterers serve as a stigma-identity construct that leads to negative psychological health outcomes. In an adjusted analysis that focuses on cohort members who stutter, PWS were found to have higher Malaise scores than their controls, indicating a higher level of psychological distress and a risk of serious mental health difficulties (Gerlach et al., 2021).

PWS are often judged to have intellectual deficits, but studies suggest that stuttering is caused by congenital genetic deletion or abnormal brain structure, and intellectual quotient is not affected by stuttering. When people treat stutterers with an impatient, contemptuous and provocative attitude, they tend to have ignorance in the fact that stutterers' intelligence and cognition are intact, which have led to mental health barriers and low self-esteem for PWS (McAllister et al., 2013). People's attitudes toward stutterers can greatly affect stutters' emotions and stuttering behaviors. For example, patience is an important trait when conversing with PWS as it encourages reciprocity and turn-taking.

The expected result of this study is to provide a comprehensive, systematic reference analysis contributing to an objective understanding of bilingual stuttering and monolingual stuttering. This review aims to provide a resolution for stutterers, by emphasizing on the atypical functioning of brains between the two types of stutterers and their differences between cognitive processes like inhibitory control, cognitive shifting, and updating of information. Thus, the study provides a summary for interventions or outcomes that already exist, and aggregate all valid data to form the bases of future research regarding the similar area.

2. Method

2.1 Literature Research

PRISMA, The Preferred Reporting Items for Systematic Reviews and Meta-Analyses, is used as the guidelines of this study (Moher, Liberati, Tetzlaff, & Altman, 2009). Stutterers without age limits are the stated objectives, and an explicit, reproducible methodology is used. Google Scholar and the PubMed database was used to search original data regarding keywords “stuttering”, “bilingualism” and/or “monolingual”, and either “brain structures”, “inhibitory control”, “executive control”, “cognitive or brian reserve”. The titles and abstracts are screened to determine their relevance to the present study, and relevant articles are evaluated for inclusion based on the inclusion and exclusion criteria. The searching process was conducted in February and March of 2023. Studies that did not meet the inclusion criteria or violated the exclusion criteria were removed, resulting in 87 references in total.

2.2 Select Inclusion And Exclusion Criteria

Inclusion and exclusion criterias regarding languages, public data, and objects were applied to studies examining the physiological and cognitive difference between MWS and BWS. Inclusion criteria required that studies: 1) are available via Google Scholar and PubMed, 2) be available in English or Chinese without time limit, 3) experiments, systematic analysis, observations are all included. Studies were excluded if: 1) their main topics are irrelevant to atypical brain structures and/or cognitive influences, 2) they were case studies, commentaries, editorials, letters, or news articles, and 3) participants were sign language users or diagnosed with an impairment other than stuttering. The current study focuses exclusively on bilingual stutterers who speak only two languages. Participants that are multilinguals who speak more than two languages both simultaneously and sequentially are not excluded by the criteria.

3. Brian Structure Disparage

3.1 Atypical Language Lateralization

Stutterers experience anatomic asymmetries in their brains. Researchers have found an enhanced right hemisphere activity in PWS within the area of the frontal opercular part, while the anterior insula and the orbitofrontal cortex are also influenced in other cases (Kell et al., 2018). Left hemisphere motor impairments are then proposed for other asymmetries in PWS (Alm, 2013). Neef (2015) further proposed that stuttering is probably caused by atypical motor cortex activation, since the left motor cortex are responsible for speech-motor plans among PWNS, while researchers didn’t examine the left hemispheric asymmetry among PWS. A negative correlation between the magnitude of neural facilitation in the left hemisphere and stuttering frequency is observed, suggesting a possible treatment for stuttering could be exciting neural connections in the left hemisphere of PWS. This treatment could be achieved by reducing stimulation of the right inferior frontal gyrus or enhancing left hemisphere activity (De Nil, 2003). These findings are limited to adults who stutter, though. Researchers assessing language lateralization between children who stutter (CWS) and children with no stutter (CWNS) found no group differences in a picture-naming experiment (Sowman, 2014). Additionally, in the case of handedness, a behavioral index for cerebral laterality associated with the presence and treatment of stuttering, researchers that lean into the area of using hand preference to relate cerebral asymmetry and developmental stuttering have found no direct correlation between handedness and children stuttering severity (Mohammadi, 2020).

3.2 Atypical Brain Structure

3.2.1 The Broca’s Area

The Broca’s area in the prefrontal cortex and the Wernicke’s area in the left temporal lobe are the two main functional cortical areas responsible for language production and comprehension, respectively. The Broca’s area is precursor to semantics (Thompson-Lake, 2022). When a person's Broca's area is damaged, language production is impaired but language comprehension usually remains intact. The cortico–basal ganglia–thalamo–cortical loop is one of the fundamental networks in the brain. It reveals cognition, sensorimotor behavior, and the natural history of many neurological and neuropsychiatric disorders. Motor, associative, and limbic channels are contained in this network (Foster, 2021).The atypical development of the cortico-basal ganglia-thalamo-cortical network reflects the anatomical basis of the abnormal inhibitory control network between Broca’s area in individuals from families of inherited stuttering. This is the first evidence of a neural phenotype with an autosomal dominant stuttering in a family inherited with stuttering (Thompson-Lake, 2022).

Previous studies show that the Broca's areas, the Wernicke's areas, and right hemisphere homologues in PWS are either over or under activated (Sakai, 2009). Researchers found that transcranial direct current stimulation is able to ameliorate stuttering severity when overactivation in the Broca’s area was reduced, which further suggests that

speech dysfluency in PWS may be caused either by functional alteration in Broca's area or by abnormal activation in speech motor control areas connected with the Broca's area (Yada, 2019).

Stuttering is shown to be related with reduction of regional cerebral blood flow (rCBF) in Broca's region, which reinforces the idea that reduction in rCBF is relative to control values, and a common pathophysiology throughout the language loop likely contributes to stuttering severity (Desai, J., 2017). This further suggests methods of treatments for PWS: looking at ways to increase rCBF volumes, or examine the whole language loop between the Broca's and the Wernicke's area.

3.2.2 Grey and White Matter Changes and Structural Connectivity

The central nervous system is made up of grey matter and white matter, where the grey matter, making up the outermost layer of the brain cortex, contributes to the normal reactions and behaviors in daily lives, and the white matter are essential sections of both the brain as well as the spinal cord (Mercadante, 2023).

Typical for grey matter, BWS has various anatomical changes in brain structure (Abutalebi et al., 2015). For MWS, the change in grey matter in the left frontal and parietal lobes is less than BWS. The same was found in simultaneous bilinguals compared to sequential bilinguals, and in proficient bilinguals compared to non-proficient bilinguals (Mechelli et al., 2004). Furthermore, white matter decreases were associated with greater language disfluencies (Civier et al., 2015). The corpus callosum, which connects the left and right hemispheres in the human brain, contains more white matter volume in bilingual older adults than in monolingual older adults (Luk, 2011). These white matter changes have been noted in various bilingual groups, including simultaneous bilingual adults (García-Penton et al., 2014) and sequential bilingual adults (Pliatsikas et al., 2015). Therefore, enhanced brain structural connectivity is apparent for BWS compared to MWS (Kornisch, 2022).

4. Cognitive Processing Disparage

4.1 Executive Functions

Executive forces are primarily controlled by the prefrontal cortex in human brains. The functions of executive forces relevant to language fluency are inhibition, including response inhibition like self-control, and interference control like selective attention and cognitive inhibition, working memory, and cognitive flexibility which includes creativity and flexibility (Diamond, 2013).

Dual-task paradigm is a common method for examining functional cerebral processing. In a study completed in 2016, researchers found that BWS have less dual-task interference than MWS, and bilingualism is shown to offset deficits in executive functioning (Kornisch, 2017). The prefrontal cortex is shown to be primarily responsible for controlling executive functions (Alvarez & Emory, 2006). Since BWNS have relatively larger magnitudes of grey matter in the prefrontal region, a bilingual advantage may be present (Abutalebi et al., 2014). Cingulate cortex controls speech fluency and links to motor control (Grahn, 2008). BWNS who develop increased grey matter in the cingulate cortex can more efficiently use the anterior cingulate cortex compared to MWNS (Abutalebi et al., 2012).

Researchers proposed that stuttering may reflect executive functioning deficits regarding self-regulation and inhibitory control (Felsenfeld, 2010). Previously, MWS are examined to have deficits in executive functions in terms of attentional functions (Heitmann et al., 2004), working memory (Bajaj, 2007), reaction time (Eggers et al., 2013), and linguistic processing (Maxfield et al., 2015). Most MWS encounter obstacles when dividing their attention between concurrent tasks (Bosshardt, 2006), while some BWS seem to perform well when engaging in cognitive challenging activities including inhibitory control and switching between different tasks (Bak, 2014). Relatively greater practice frequency with languages appears to be a possible reason for the bilingual advantage, because the cognitive control required for mastering two languages includes the ability to inhibit one language and switch between the two languages. Nevertheless, when investigating pre-school children, researchers did not find a distinct bilingual advantage. In a study for preterm and full-term preschoolers, parents' rating and performance-based instruments reveal neither positive nor negative relationships between bilingualism and executive functions (Loe IM, 2016). Arizmendi et al. (2018) examined inhibition, shifting, and updating among 7-9 aged children, and revealed no evidence of a bilingual advantage in executive functioning. However, the results of these children's research may obtain bias that fails to consider the fact that children's cognitive development takes time, and studies that report a bilingual advantage often possess a small sample (Kornisch et al., 2022). Still, executive functioning warrants further examination (Paap, 2015). Van den Noort et al. (2019) found that convergent validity is relatively low in studies indicating a bilingual advantage, so the better or worse executive functioning in BWNS may be caused by methodological differences in various studies, rather than actual disparages in participants' inhibition, shifting, and updating capacities. Also, the definition of bilingualism,

including the standards of being a bilingual stutterer, varies between different studies (Choo, 2020). Kornisch et al. (2017) reveals that the use of no-standardized assessments, neglect of individual differences, and lack of longitudinal studies are possible causes of the invalidity of studies indicating bilingual advantages. More research is needed in which standardized approaches are implemented. For now, it does appear that bilinguals have an advantage in executive forces on most tasks.

4.2 Neural Reserve

Neural reserve, including cognitive reserve and brain reserve, is a result of a higher neuronal density in brainstem aminergic nuclei, which is influenced by lifestyle choices (Wilson RS et al, 2013). Cognitive reserve is the brain's ability to improvise and find alternate ways of completing a task, and can be developed through cognitive training or education (Harvard Medical School Published, 2023). Brain reserve is the ability of the physiologic system to maintain function despite damage from injury or disease, and a resilient force that works against the effect of neuropathological processes on cognitive outcomes (Saczynski et al., 2014). Both enhance the tolerance to brain pathology, and are closely related to the executive control system (Grant et al., 2014). When facing complex and demanding jobs, a brain with greater neural reserve is more efficient and able to recruit additional resources to overcome the difficulty.

In the current schools of studies regarding disparages between the neural reserve of MWS and BWS, research is limited to the examination of the executive functioning advantage in bilingualism, and rarely go further into discussions of cognitive or brain reserve, given that executive functions pave the foundation for enhanced neural reserve. A way of obtaining neural reserve is the increase of grey and white matter density in human brains, enhancing brain connectivity (Kornisch et al, 2022).

However, the results regarding neural reserve and executive functions vary among studies. BWS may develop superior executive functions with their increased white matter connectivity (Luk et al., 2011) and grey matter density (Abutalebi et al., 2014). Conversely, other PWS indicate decreased executive functions with decreased white matter connectivity (Beal et al., 2013; Cai et al., 2014; Chang et al., 2008, 2015; Civier et al., 2015; Connally et al., 2014) and grey matter density (Beal et al., 2013; Koenraads et al., 2020). Therefore, the white matter volume influence towards executive functions are not as clear as the grey matter volume changes, and thus requires further studies.

5. Emotional Based Stuttering

Emotional reactivity is the degree of emotional responses, including the frequency and intensity of emotion, threshold of arousal, negative response to challenge, and autonomic reactivity. Emotion regulation is the management of emotional responses to arousal and the ability to moderate tendencies to be aroused. Studies that now exist haven't examined a distinct difference regarding emotional responses among BWS and MWS. The emotional challenges and responses prevail for all PWS. Most studies regarding emotional based stuttering examine preschool-aged kids. CWS experience a more reactive emotional response, weak abilities to regulate emotions, as well as poor attention regulation, contributing to the difficulties when producing fluent speech. CWS show disparages in temperaments and emotions compared to CWNS (Karrass et al., 2006). Researchers can only match childrens' temperamental profile to clinical treatment exclusively, and use temperaments as a predictor of treatment outcome (Jones et al., 2014).

The association between CWS's positive emotional reactivity and stuttering is weak, while negative emotions are more associated with these children's stuttering experience (Choi et al., 2016). Anxiety does not appear to be the initial biological cause and etiology for stuttering, but can lead to short-term stuttering in conversational situations. Several research suggests positive correlation between anxiety level and severity of stutter; however, in a study conducted in 2014, PWS were no more anxious than their no stuttering peers, and associations are not found between different severity groups, ages, or sexes (Craig, 2014). Interestingly, a paradoxical response in heart-rate is discovered in PWS before going to present a public speech: when people anticipate anxiety, their heart rates are reduced (Alm et al., 2004). Anxiety in PWS warrants further research, since much of the research on this topic is often biased. The samples are not collected from random selection and assigning, resulting in poor external validity (Craig et al., 2003). If there is an actual causal effect, neurological treatments to reduce anxiety levels or feelings before giving speech may be a partial solution to stuttering.

6. Implications and Possible Limitations

For clinical treatments of stuttering: a) alterations in lateralization of the brain, the grey and white matter volume, and circular blood flow are all addressed to be efficient in some of the samples collected; b) being a BWS are more likely to result in better executive functioning than MWS despite studies that disapprove the bilingual advantages;

c) trainings for neural reserve, attention centralizing, and other cognitive abilities are helpful. However, these treatments are based primarily on studies regarding English speakers, so more inclusive data should be considered when treating stutterers who speak multiple languages other than English clinically.

For people who know little about stuttering, the article tries to form an objective and refreshing understanding towards the diagnosis that 80 millions of people are currently suffering from. According to findings that stuttering severity is affected by anxiety which can be caused by unfamiliarity (Brundage et al., 2022), a possible implication for clinical treatment would be to let PWS actually get to know what stuttering is by describing and observing the performance, development, and etiology of stuttering, so that PWS can have a better understanding of their condition. The better prepared stutterers are, the more likely they are going to know and thus change what is going on, because people tend to deal better with familiar conditions and make progress without much fear and anxiety. Stutterers are generally able to express the words and sentences completely, but they require a certain amount of time. According to analysis and self-reports from PWS, the primary obstacle that they face in daily communications is impatience from people around them. The negative experiences of being belittled by communicating objects often leads to self-debilitation. The change of this general situation needs efforts and patience from PWNS. Due to limited access to research articles and information resources in the physical IP region, some of the studies and references are blocked from the analyzing process.

7. Conclusions

The article provides a systematic analysis of the disparages between BWS and MWS regarding the brain structures, cognitive processing, and emotional based stuttering. More specifically, atypical lateralization, Broca's area, and the atypical volume of grey and white matter, executive functions, cognitive and brain reserve, emotional responses and anxiety are discussed.

The disparage between BWS and MWS exists in following ways: a) BWS have greater grey and white matter in cerebral cortex, while MWS tend to have less; b) BWS experience greater neural connectivity than MWS, likely due to countless language switching and inhibitory control trainings; c) executive functions in BWS are more powerful than MWS in older children; 4) the current research did not find any differences in emotional regulation between BWS and MWS in daily stuttering situations. These findings again address the initial purpose of the current study to provide a comprehensive, systematic reference analysis contributing to an objective understanding of stuttering. It helps both PWS and PWNS develop a detailed understanding towards bilingual and monolingual stuttering. Therefore, may people give a minute to hear what the stutterers say, while enhancing the overall well-being of people who struggle to be fluent in the most basic communications of life.

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