Language and Aging: A Neuro-Cognitive Assessment of Aging Across the Lifespan

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Abstract

As we age, there is often some degree of cognitive decline. Difficulty with speech comprehension and language production often provokes frustrating experiences across the lifespan, especially in older adults. These encounters do not solely influence cognition, but also human perception and interaction within society (Hummert et al., 2004; Kemper, Finter-Urczyk, Ferrell, Harden, & Billington, 1998). Interestingly, studies have indicated that language comprehension is maintained as language production declines. While aging is frequently linked to detrimental effects in speaking, there is still a clear sense of knowing the word. There are competing theories regarding the underlying causes of age-related deficits in and speech, such as transmission vs inhibitory deficits, compensation and dedifferentiation, and processing speed. These cognitive changes are associated with neural decline, and word retrieval failures. Studies have presented the notion that older adults are often slower and less efficient compared to younger adults, raising the possibility that retrieval issues may be influenced by age-related declines in phonology and processing speed. In this study, we looked at two factors that might influence speech: phonology and frequency. One aspect of the study stresses the connection between phonological neighborhood density (PND) and word retrieval failures to develop our understanding of the neurological and behavioral foundations of age-related deficits in speech. In correlation with PND's, high frequency words (apple, cat, house), also have been shown to have a notable influence on word retrieval. Retrieval deficits often occur when individuals encounter words with sparse phonological neighborhoods as well as low frequency words (banjo vs cat). We are interested in how cognition, age, and the brain affect language production. Here, we used the picture naming task to examine reactions times and activation levels across the lifespan. The experimental study analyzed the number of neighbors a word has in correlation with high frequency words to interpret whether this changes the way we process information.

Introduction

Although some aspects of language remain intact throughout adulthood, such as intellect and language comprehension, there are cognitive problems associated with word retrieval (CITE). In past research, we observed notable negative effects on speech and aging. The cognitive problems associated with word retrieval failures have been reflected in previous studies, such as ToT (Tip of the tongue states), in which an individual is not able to accurately produce a word even if there is a vivid sense of knowing it (Burke et al., 2004; Burke et al., 1991; Maylor, 1990; Rastle and Burke, 1996). Other age-related declines in speech associated with production include phonological neighborhoods and the facilitation of production. In this study, we look at two factors that may influence speech: how a word sounds (phonology) and how often a word is encountered (frequency). The more phonologically similar neighbors a word has, the greater the surge of priming to target phonological representations and the faster they will reach threshold (Vitevitch & Sommers). The overall goal of this current research is to improve our understanding of the neural and behavioral bases of age-related declines in speech by analyzing where speech deficits occur, and the retrieval of phonological information appears to decline with aging (Burke and Shafto 2004; Mortensen, Meyer, & Humphreys, 2006). Retrieval deficits often occur when individuals encounter words with sparse phonological neighborhoods as well as low frequency words such as banjo vs cat. (Landauer and Streeter, 1973). We aim to integrate theories to explain why deficits occur through fMRI studies of language and production to find the link between language production and behavioral performances (Wlotko et al. 2010).

Inhibition Deficit Theory: Link Between Working Memory and Comprehension

There are several theories about why older adults have language production difficulties. The link between working memory and comprehension led to the development in the inhibitory deficit theory (Hasher and Zacks 1988; Lustig et al. 2007). This theory suggests that older adults process more information compared to younger adults, but this may prevent them from completing the task at hand (Healey et al. 2008). Functions of inhibition may include controlling entry to one's focus, the ability to control inappropriate responses, and deleting irrelevant information from working memory. Working memory has shown the largest age effect (Bopp and Verhaeghen 2005) and may have a mass impact on language processing and executive function. Working memory, specifically executive function, may impact language processing in older adults. This notion is supported by additional studies supporting this hypothesis, illustrating that increasing working memory demands in older adults resulted in slower speech rates (Kemper et al. 2003). Inhibition deficits may increase information entering working memory, even if this information is not dedicated to task success. The inhibitory deficit theory also suggests that attentional performance may be impacted by age-related declines in the capacity to suppress irrelevant information. (Lustig et al. 2006), reading speed (Carlson et al. 1995; Connelly et al. 1991), memory (Collette et al. 2009), and pattern learning (Kramer et al. 1994), suggesting that such a deficiency may be responsible for changes in a wide range of cognitive functions, including some aspects of language. This may contribute to the notion that older adults are less able to ignore irrelevant thoughts and actions than young adults (Lustig et al. 2006), as well as why older adults often generate off topic speech (e.g., Arbuckle, Nohara-LeClair, & Pushkar, 2000). Declines in inhibition support the notion that age related declines in inhibitory control result in an increase of information entering working memory, which may impede them from completing the desired goal (Hamm and Hasher 1992). This may contribute to the underlying language production deficits. In terms of capacity, performance should improve across a wide range of tasks depending on the amount of preserved mental disk space. Although older adults may be able to process more information, it might divert them from finishing the task at hand. A variety of cognitive functions can change because of age-related deficiencies in the capacity to suppress irrelevant information, including memory, pattern learning, and attentional performance (Lustig et al. 2006). Although older adults can still access inhibitory processes, they may find it more challenging to activate strategies that lead to success making it increasingly difficult to ignore irrelevant thoughts, resulting in slower retrieval times. (Diaz. Et. Al).

Transmission Deficit Theory: Age-Related Differences in Language

There are competing theories as to why older adults have language production declines such as cognitive slowing, inhibition deficits, and phonological deficits. There is evidence suggesting that the evidence is consistent with the transmission deficit model, which explains that ageing weakens connections between semantic and phonological representations of verbal knowledge (Burke and Shafto 2004). Contrary to the inhibition deficit theory, declines in inhibition support the notion that age related declines in inhibitory control result in an increase of information entering working memory, even if the information is not for task success. Older adults are not unable to recruit inhibitory processes but may experience increased difficulty initiating strategies that lead to success (Murray et al. 2015). The transmission deficit theory was put forth to explain how language changes with age, and to make predictions about language development. In contrast to the inhibition deficit theory, the TDT theory overall puts the focus on connections between nodes within semantic and phonological networks that are weakened with age (e.g., Thornton & Light, 2006), while the inhibition deficit theory emphasizes the age-related neural declines in working memory and comprehension (Hasher and Zacks 1988; Lustig et al. 2007).

The Transmission deficit theory makes specific predictions about language such as declines in frontal and superior regions with more posterior and inferior regions displaying less decline in older adults (Diaz et al 2016). Language production relies on the frontal gyri, which may also explain the deterioration of production across a lifespan. The connections between nodes within semantic and phonological networks are weakened with age, reducing the degree to which one node can prime (process that triggers retrieval) another node (MacKay and Burke 1990). The age – related weakening of connections will limit the transmission of priming from lexical nodes to associated phonological nodes, reducing the likelihood of phonological activation, which is why the transmission deficit theory is linked to higher word retrieval deficits in older adults (James and Burke 2000). Infrequent or nonrecent use of a word and aging of the participant weaken connections to and within the phonological system (Burke et al., 1991; Burke & Shafto, 2004). Although the semantic and phonological systems are interconnected, the semantic system is more interconnected than the phonological system (Burke et al. 1991; James and Burke 2000; Laver and Burke 1993). There can be a weakening across the network, but the phonological system is the most vulnerable. This decline in production may contribute to age related declines in phonology (James and Burke 2000).

The transmission deficit theory is unique to language and production decline since vocabulary and semantic knowledge improves over a lifespan. The phonological system appears to be the most vulnerable (Burke and Shafto 2004). Inhibition is more generalized in the sense that inhibition of information which is irrelevant to one's goals is a key contributor to differences in performance among individuals. One of the reasons why we compare the IDT vs. the TDT is because they make different predictions. For example, in contrast to what the TDT suggests, if older individuals experienced inhibition deficiencies, this would signify that they really had more activation (stronger phonological priming, stronger semantic priming, etc.). To evaluate where exactly retrieval deficits are occurring, we conducted behavioral assessments aimed at examining declines in inhibition, processing speed, language production, and phonological neighborhood density. Although word retrieval skills deteriorate with age, there is evidence to explain why these deficits are occurring: Compensation vs dedifferentiation.

<u>Compensation vs De-differentiation</u>

It is evident that word retrieval failures may be associated with compensation. Compensation refers to the recruitment of more regions to fulfill the task at hand, this illustrates how an individual uses resources in response to task demands. When there is a high cognitive demand, compensation refers to the improvement in cognition that occurs when resources are enlisted; this may differ between older and younger persons (Good et al. 2001; for a review, see Madden et al. 2012; Resnick et al. 2003; Salat et al. 2004). While studies in younger adults have shown to prefer a more challenging and more rewarding process, a common observation in fMRI studies with older adults is bilateral patterns of activation (e.g., Gerlach et al. 1999; e.g., Tyler et al. 1995; Wright et al. 2012). Younger adults have more unilateral patterns of activation, while older adults promote increased activation within the brain (Logan et al. 2002). The key to interpreting patterns of activation is to identify maintained or improved performance. compensatory processes or dedifferentiation. People up regulate to perform better, but research suggests that it results in dedifferentiation (Diaz et al. (2014). Older adults often recruit more regions to compensate for regions lacking in retrieval, which may be counter intuitive. Older adults upregulate and are more sensitive to contextual information (Madden 1988), since they are unable to keep up with the information like younger adults. When task difficulty increases, there may be an increase in brain activity that does not actively support performance on a production task. Brain activity typically rises until it hits a threshold, after which it begins to fall (Diaz et al 2016). The activation of brain circuits related to cognitive abilities that younger adults have access to but do not employ for the task at hand may be used to predict trends in recruitment. While older adults might prefer a less challenging but less rewarding strategy, younger people might favor the opposite. Although younger adults can recruit through the same processes, it is less likely to improve their performance (Cabeza et al. 2002). As we age, there may be connections so weak that they respond poorly to phonological cues, this is where dedifferentiation occurs in the pre-frontal cortex (e.g., Cabeza 2002; Ghisletta and Lindenberger 2003; e.g., Park et al. 2004). We see evidence in age related decline in phonological sensitivity. Although adults can do the task, they are sensitive to it (Madden 1988), which results in de-differentiation. Making the connection between compensation and effective performance makes it easier to tell if activation differences are the result of dedifferentiation or inefficiency. (Diaz et al. (2014)

<u>The Present Research</u>

In the present study, we study how PNDs, and high frequency words predict increased accuracy in word retrieval by analyzing when deficits occur, and why adults have language production declines. Older adults have larger vocabularies, but both younger and older adults display similar word associations. This indicates that both age groups exhibit semantic priming effects, which computes to spreading activation through associative networks. This brings up a key factor in age related deficits: language comprehension. The Inferior Frontal Gyrus (IFG) is the primary cognitive control function, primarily the left IFG as it supports executive function (Braver et al. 1997; Dove et al. 2000; Moss et al. 2005; Swick et al. 2008; Zhang et al. 2004). The right IFG seems to contribute to language comprehension successfully but does not support successful behavior during language production. (Geva et al. 2012) Comprehension remains intact as we age. Since semantic aspects of comprehension change less as we age, the ability to utilize comprehension and memory retrieval is preserved throughout the lifespan. Processing speed may also contribute to differences across memory tasks due to declines in working memory. For example, older adults do not seem to utilize predictive information the same way young adults do (Federmeier and Kutas 2005). Meaning that guiding behavior requires the brain to process information at higher activation which older adults may not possess. The link to the reorganization of the dorsal stream may predict structural deterioration within the brain. Even though some parts of language processing have a significant left lateralization, recent research indicates that as people get older, the right IFG is more commonly recruited, creating a more bilateral dorsal stream. (e.g., Tyler et al. 2010a; Wierenga et al. 2008). Language production also seems to recruit IFG, regardless of age, like language comprehension does. It has been noted that older adults recruit to this area during semantic (Meinzer et al. 2009; Meinzer et al. 2012b) and phonological verbal fluency tasks (Meinzer et al. 2009). These findings show that in older adults, at least one key language region of the left-lateralized dorsal stream still plays a significant role in language production (Vigneau et al. 2011). While studies in younger adults have shown that greater phonological overlap elicited less activation in younger adults, a common observation in fMRI studies with older adults is bilateral patterns of activation (e.g., Logan et al. 2002). Our hypothesis states that increased phonological overlap in correlation with frequency will predict increased accuracy in word retrieval.

Methods

Participants and Design

Participants in this cross-sectional study of language deficits and aging were _40__ adults from the ages of 18-89 (M age =47.00, SD age= _19.17). Participants recruited had to meet necessary requirements before being eligible for the study. In order to evaluate age-related variations in language production, participant ages were distributed across the lifespan (see Fig. 1 for a histogram of the age distribution). All participants were right-handed, monolingual, and had little to no exposure to other languages. This was an important factor to incorporate because evidence has suggested that bilingual individuals often make use of the brain differently None of the subjects had serious neurological, psychiatric, or physical issues (Christensen et al., 1992), and all had normal or corrected-to-normal eyesight. It was necessary for the participants to be right-handed; since language is oriented in the right hemisphere, left-handedness demonstrates bilateral activation, and the MRI averages patterns of activation. It was also important to decline people who take prescription medications for mood, such as anti-depressants, anti-anxiety medications, or mood stabilizers as it affects the brain. This is also true for people with major medical conditions such as cancer, diabetes, or heart disease with at least a 6-month remission phase. Participants also had to have at least graduated high school in order to reduce potential outliers.

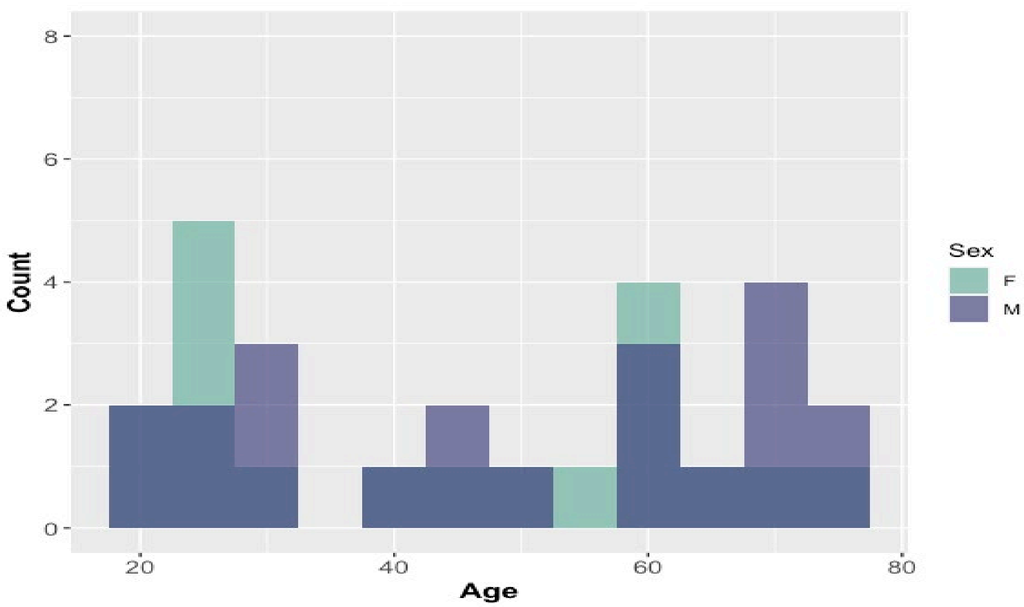

Figure 1 – Distribution of participant's age. Forty adults, roughly evenly distributed across the lifespan. Mean age = 47.00, SD age = 19.17)

Apparatus: Surveys, software used for data collection, MRI (Magnetic Resonance Imaging)
Measures: Neurocognitive tests, self-report measures of attitudes

Prior to the in-person session, each participant completed a series of neuro-cognitive tests to assess levels of cognitive functioning, such as working memory, speed, executive function, and language. A Qualtrics survey was included to assess cognitive impairments, where we collect data related to demographics as well as information used to screen out participants due to cognitive impairments. This included demographic info, the geriatric depression scale (GDS) to screen for depression(Yesavage et al., 1982), the WAIS vocab task to assess language/reading abilities, author recognition task (ART) to assess reading habits, and a color vision test (Ishihara plates) to assess for color blindness These psychometric tasks also included the MoCA (Montreal cognitive assessment) to screen for mild cognitive impairment or dementia; WAIS-III vocabulary, digit-symbol, and digit span subtests to assess working memory (Wechsler et al., 1997); phonemic (F, A, S) and semantics (animals) categories to screen for verbal fluency (Patterson, 2011); the author recognition test to assess reading habits (Acheson et al., 2008); the California Verbal Learning Test to assess immediate and delayed memory (Woods et al., 2006); simple and choice reaction time tests to assess speed 3 ; a reading span task (Conway et al., 2005; Loboda, 2012), a computerized version of the Stroop task (Stroop, 1935), and a story elicitation task. Age was significantly inversely correlated with measures of working memory and word retrieval and significantly correlated with measures of speed (simple speed, choice speed, and digit symbol) and inhibition (Stroop) (backward digit span, verbal working memory, immediate and delayed recall). Although word retrieval is higher in younger adults, we observed no significant changes immediate and delayed recall across the lifespan. In previous studies, age and reading preferences were positively connected, with older adults reporting greater author familiarity (ART task), It has been translated as more reading experience (Acheson et al., 2008).

The verbal fluency tasks' widespread use is partly due to its connection to executive functioning. Participants must access words from their vocabulary, which requires access to the mental lexicon. It requires concentration and identifying specific words accurately., all of which need executive control processes. (e.g., Fisk and Sharp, 2004). Thus, deficient performance in the fluency tasks should be a sign of vast verbal ability or executive control deficiencies. Prior to the MRI session, we schedule an in-person session where we administer a computerized version of a series of tasks including a speed task (processing speed), choice reaction task (ability to process more info), a Stroop task (attention capacity/counterbalance), vision acuity test (FracT) assessing if participant has normal/corrected to normal vision), the Pitt reading span (make judgement whether a sentence is right or wrong), and verbal memory (immediate/delayed recall of a series of words). Then, we may correlate the findings with fMRI data analysis.

Stimuli and Procedure

Here, we used the picture naming task to examine reactions times as we measure phonologically dense neighborhoods. This experiment analyzes how PND's, and frequencies of words interact, then we will be able to interpret whether this changes the way we process information. By integrating theories in behavioral findings and the linkage between behavioral performance and age-related differences, we can accurately identify underlying causes of age-related deficits in speech. The overarching goal is to conduct behavioral assessments of cognitive abilities in older and younger adults aimed at examining inhibition, speed, and language function. We collected data on declines in inhibition, processing speed, and phonological aspects of language to analyze how the brain operates when processing language.

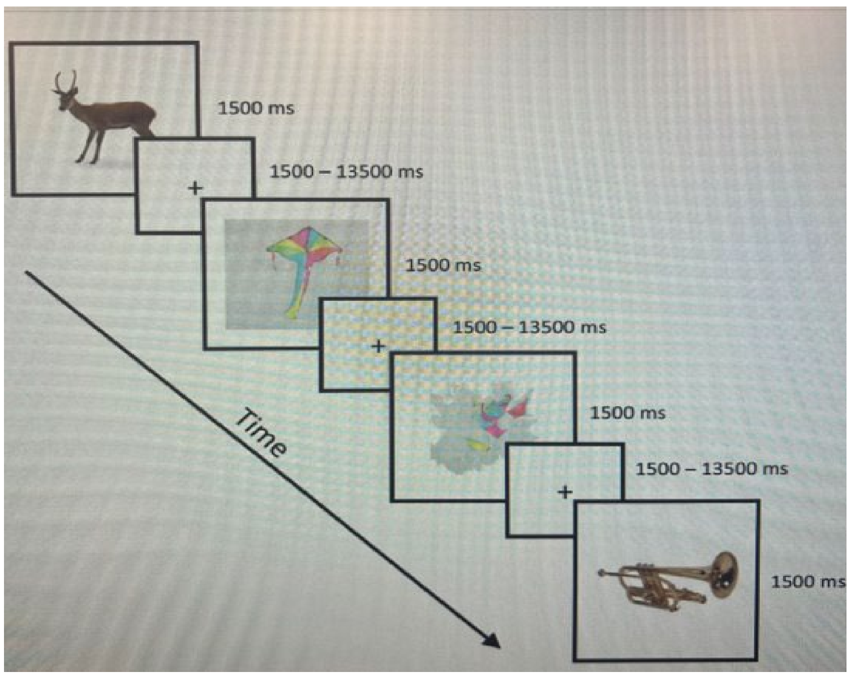

Figure 2 - Participants named diverse pictures in phonological neighborhood density (e.g., deer, kite = high PND, trumpet = low PND), and abstract pictures (control condition) (Diaz et. al.)

In this study, we look at two factors that may influence speech: phonology and frequency. The denser the word, the more difficult it is to produce, the less frequent, the more difficult it is to retrieve. To examine how cognition, age, and the brain affect language production, we administer a picture naming task. Participants performed a picture naming task in the MRI scanner. Each trial consisted of 191 photographs, presented over a white background. Participants were instructed to overtly name the photograph as quickly as possible while still responding to the picture precisely. Participants were also asked to be as specific as possible in their answers (e.g., toast instead of bread).

To control for brain activation to basic visual and motoric features, we included a control condition that consisted of 50 photographs that had been abstractly transformed to yield unrecognizable objects that maintained the basic characteristics of a recognizable photograph. This is to control the brain's response to visual and motoric elements. Images depicted common concrete objects from a variety of categories such as animals, clothing, food, and household items. To assess PNDs in correlation with high frequency words, we included a combination of high frequency words and phonologically dense words to assess reaction times based on the frequency of PNDs and frequent words. High frequency words and PNDs were varied across the items to allow us to investigate whether an increase in words retrieval was observed based on these factors. Words with high phonological conditions (moth, cloth, broth), are high phonologically, but we do not see these words often (frequency). The picture naming task helps determine whether words with high PND in correlation with higher frequency of the words result in higher word retrieval. We then record the reaction times to assess how this changes the way we process information. This experiment will analyze how PND's, and frequencies of words interact, then we will be able to interpret whether this changes the way we process information.

During the MRI portion of the study, we assess for disfluency with words that have dense neighborhoods. The participants were prompted to participate in the MRI portion of the study to analyze activity within the brain. This is the most critical aspect of the study and was performed to measure the phonological neighborhood density to measure how individuals interpret sound patterns and meaning. The picture naming task is a language production task. Visual perception, recognition, and the addition of nonverbal conceptual understanding of the depicted item are the first steps in the picture naming process. The next two levels of lexical access are as follows: A lexical phonological representation is accessed after accessing a lexical semantic representation (the phonological word form, or lexeme) (Graves et al). We manipulate a variety of pictures and focus on a specific target name to link the lexical phonological form to semantic information that is recalled through activity within the brain (Graves et al). When a node is has frequently been activated over the course of a lifetime, the rate and amount of priming transmitted across its connections increases (MacKay, 1981;1982). Stronger connections between lexical and phonological nodes for words with high frequency tend to prevent phonological errors, which often happen when an incorrect node in a phonological domain receives more priming than the correct node when the activating strategy is applied. The likelihood of word substitutions for low frequency words over high frequency words may be explained by the frequency factor. (Stemberger, 1984) and why object naming is faster for high than low frequency names (Huttenlocher & Kubicek, 1983; Oldfield & Wingfield, 1965). Phonologically, if we insert, delete, or substitute a phoneme for sound such as cat, hat, at, scat, we can predict higher retrieval rates in older adults. The number of neighbors a word has creates higher activation density and refers to how dense the network is (number of connections). (Vitevitch & Sommers, 2003). We examine word disfluency with densely populated neighborhoods in the MRI machine, where we monitor how long it takes for them to speak. The terms are less common and more difficult to pronounce depending on the density of the word. After the participant says the target word, we assess the responses correctness. This is to assess how the brain processes language in congruence with reaction time and phonological density.

Behavioral Results

Older adults are often slower and less accurate in the picture naming task, pointing to cognitive slowing (Morrison et al. (2003). Task difficulty in congruence with low density words was dependent on analyzing activation levels in the brain. For the MRI analysis, we observed regions which produced the highest levels of activation in congruence with PND increases/decreases and task difficulty. We analyzed activation levels within the brain and noted the activation levels based on the frequency of the word and PND. We were interested whether high frequency of a word predicts higher retrieval vs high frequency of PNDs through analysis of the brain via optiBET. This is where we analyze whether compensation or dedifferentiation is prevalent across the lifespan. Higher level cognitive processing is more significantly impacted by age-related deterioration in sensory processing. For the same task, different brain regions are active in various situations (older vs younger), consistent with the MRI, there does not seem to be any behavioral variance in reaction time. We can examine if age disparities are constant throughout the course of a lifespan by enlisting more brain regions. We were able to foresee that there are noticeable variations, but they are not particularly significant. Connections between nodes become stronger or more efficient with use. Although we use our entire brain, this is not always the most effective use of it. Since it is more effective to execute activities more effectively, we desire components to be more specialized- this is what is seen in older adults. When we recruit too many regions of the brain, networks become subject to dedifferentiation (Diaz et al). Adults recruit more data; however, it is hypothesized that they overrecruit in other regions to make up for other regions where they underrecruit. The results of behavioral outcomes depend on comprehension and dedifferentiation, which is analyzed via optiBET (brain extraction script).

Preliminary Findings and Results

In order to determine the impact of PND, Age, and the relationship between PND and frequency, we used a scatter plot regression analysis. In order for the manipulation to be effective, ex- act congruence in the onsets was necessary because our analyses primarily focused on phonological neighborhood characteristics (M.T. Diaz, H. Karimi, S.B.W. Troutman et al. Neuroimage 225 (2021) 11751), and all other responses were classified as errors. Responses were coded for accuracy based on the exact response of the given word in response to the MRI picture naming task. Since we are assessing for disfluency, the target word must be exact due to the PND. Subcategories of errors were created, and the responses were used to assign scores. Acceptable alternatives (stick, branch), word retrieval failure (uh, I don't know), phonological disfluency in which sound is the same as the target response ("Muh" "muzzle"), semantic disfluency ("pi. Pickle" "cucumber"), or if the first word was incorrect, but the response was accurate ("uh" ... "glasses), and an incorrect response. We also included an abstract photo in which a participant was to respond "picture", acting as the control condition. Although we detected no significant age differences in the phonological and frequency variable, we notice a stronger age difference in the phonological condition in comparison to our frequency condition. We predict that we will detect more distinct age differences in the future.

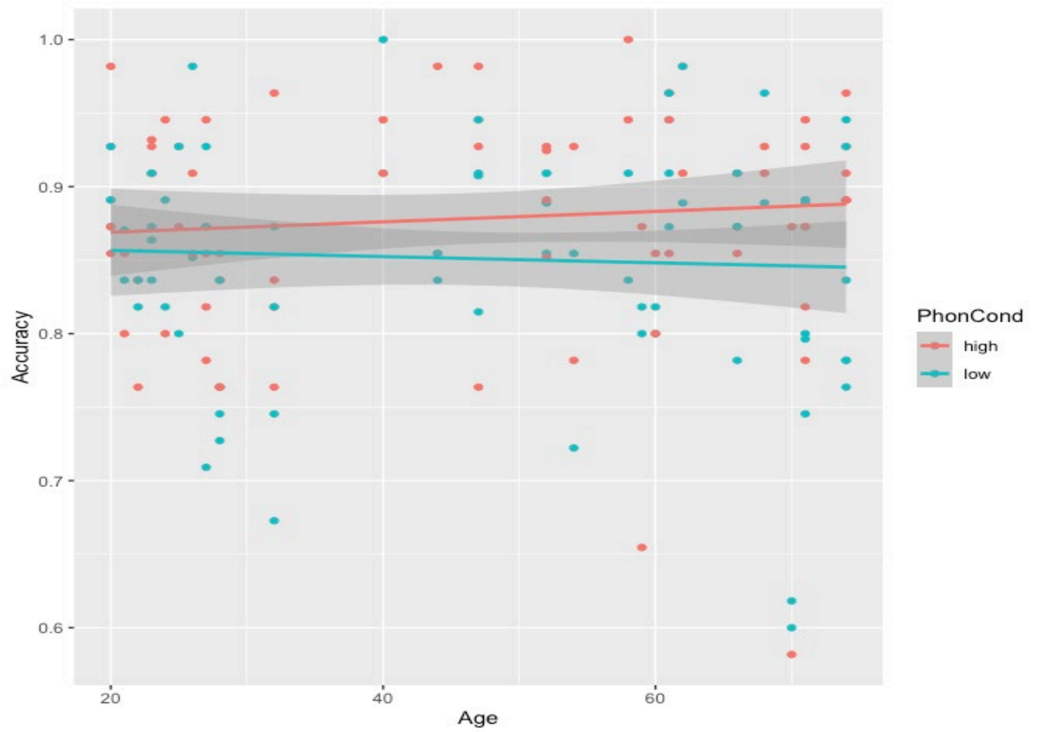

Figure 3 - Phonological Condition and Accuracy

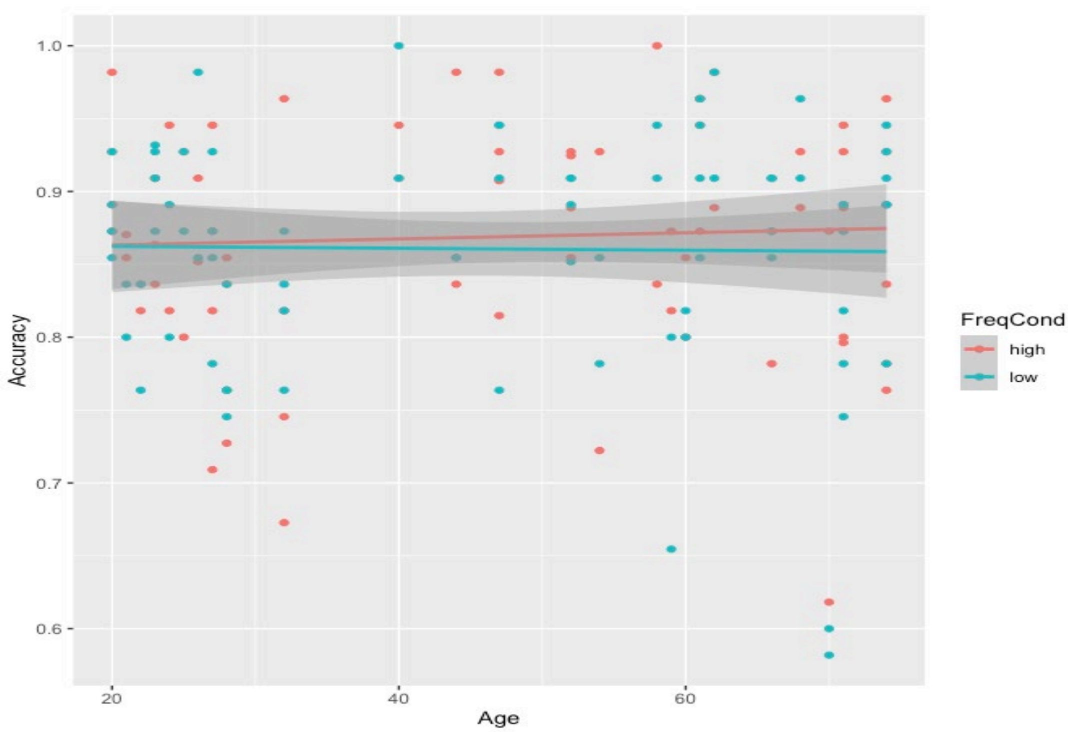

Figure 4 – Frequency Condition and Accuracy

For the MRI analysis, we observed regions which produced the highest levels of activation in congruence with PND increases/decreases and task difficulty. Based on a previous study analyzing retrieval rates of PNDs, there were no strong age-related differences in sensitivity to phonology, there were age-related differences in picture naming (Diaz. Et.al) We were interested whether high frequency of a word predicts higher retrieval vs high frequency of PNDs. Although phonological neighborhood density portrayed a more significant effect, it was evident that there was no significant age difference between PND and frequency. This may be due to the relatively small sample size (N=40). In future data analysis, we aim to recruit a larger and more diverse sample to see a more significant age difference. In correlation with our neuropsych data, we used a pairs panel to calculate the mean for semantic and phonemic(N=0.46) (Fig. 5). We noticed a stronger age difference in phonemic. In future data collecting, we can predict stronger age-related differences in verbal fluency.

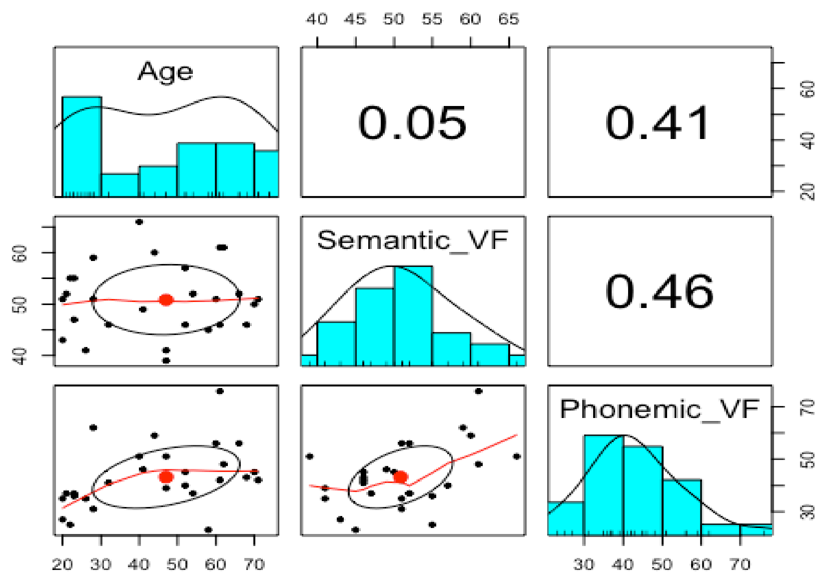

Figure 5 – Semantic and Phonemic Correlations.

We ran a pairs panel correlation test (figure 5) to predict retrieval rates (delayed recall) in correlation with our measure of reading (Author Recognition Task). Our findings indicate that there was no significant age difference between the two variables. No significant age difference was detected, although older adults are less accurate in retrieval times. However, this may also have to do with our small sample size. What can be found unusual is that the age differences between PND and frequency are not significant. However, we did notice more distinct age differences in the data collected from the MRI analysis (refer to figure 3), so the presented p-values are unlikely to be relied on.

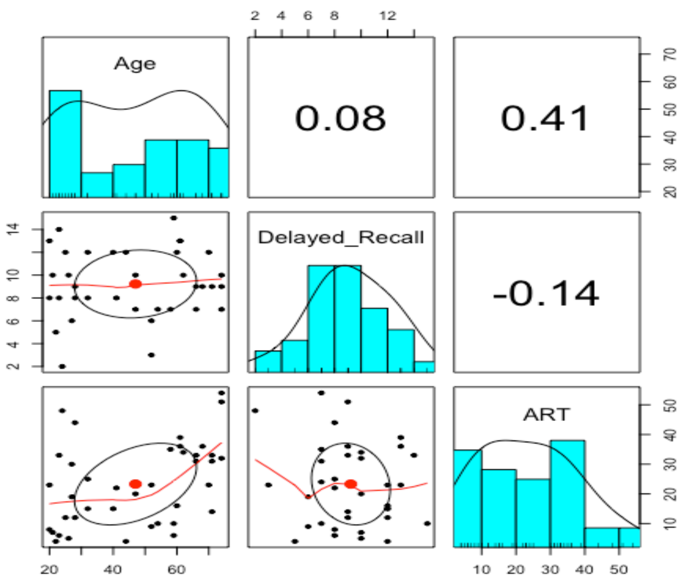

Figure 5- pairs panel correlation test (delayed recall, ART).

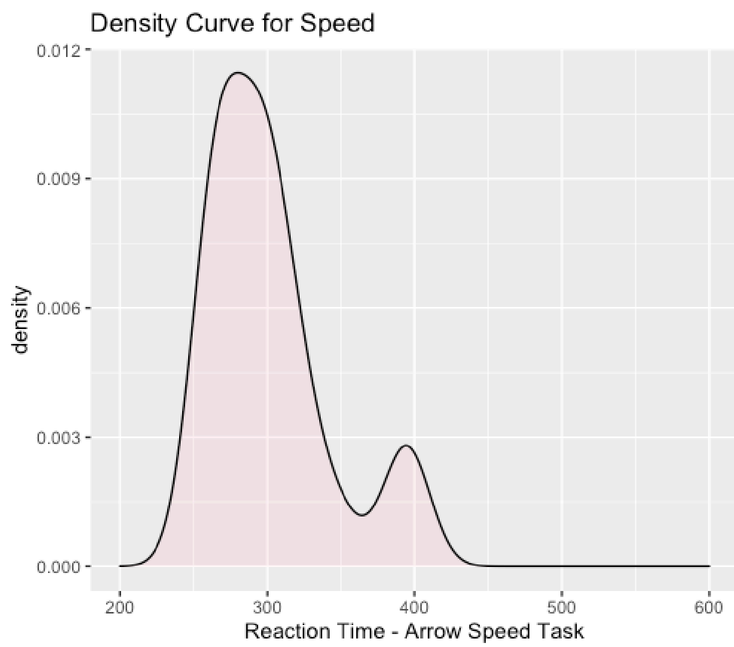

Figure 6 – Density curve to analyze processing speed (Speed arrow task). Processing speed may contribute to differences across memory tasks due to declines in working memory.

Discussion

Our sample size consisted of 40 participants, which is a significantly small population. Additionally, 3 of the 40 participants had been excluded from the study due to covid reasons and a low MoCA score. Given this, there is a lack of variability to determine the hypothesized causes and effects of aging and language across the lifespan. Also, there is the limitation of the measures we used such as the Qualtrics survey. Since one of the behavioral sessions is self-administered, there is a chance of bias in question-answering in verbal fluency (ART). Therefore, there is a lack of reliability in the scores for each participant. More importantly, we did not get to analyze activation levels in the brain via optiBET, so we cannot conclude where comprehension vs dedifferentiation is occurring. Based on the results, we hope to see a significant age difference in correlation with PND and frequency and its effect on word retrieval.

Limitations

Limitations to consider in our findings would be the small sample size (N=40). In immediate and delayed recall, even though older adults are more likely to have word retrieval failures, there was no significant age difference We could anticipate a stronger impact of phonological neighbors on language output if inhibitory deficits decline with age because if more phonological neighbors are engaged, this might increase the activation of the intended target. In this study, we found no significant age differences in correlation with PND and frequency of words. No linear correlation was found between age, PNDs, and frequency, indicating that there is no direct relationship between PND and frequency. Therefore, PND in correlation with frequency of words, may show a significant age effect in the future

The question stands on whether we will notice distinct age differences in the future. There is a sense that words with dense neighborhoods do predict increased word retrieval, as we saw in the graph, so for the data to show no distinct age difference in PND and frequency, may indicate an error in the methodologies. Further studies may involve collecting data from a larger sample size as well as integrating older adults into our data set. The study also focuses on brain imaging analysis via optiBET. The results would underline the role of the left hemisphere language regions (precentral, supramarginal, and inferior frontal gyri) and bilateral superior temporal gyri in phonological processing. In previous studies, fMRI results showed that objects with more PNDs generated less activity, which may be interpreted as facilitation, primarily in bilateral superior temporal gyri, and bilateral lateral occipital cortex, regions that support phonological aspects (Heim et al., 2003; Vaden et al., 2010). However, we do not currently have results to find exactly where the age differences are occurring to determine compensation vs de-differentiation.

Previous studies in PNDs and aging have suggested that throughout the lifespan, results in brain sensitivity to phonological neighborhood structure is maintained, but retrieval difficulty—as indicated by more errors and functional activation—increases with age (Diaz et al). Overall, evidence suggests that the transmission deficit theory best accounts for age-related changes in language production, even though processing speed and inhibitory control may contribute to trends in the data that have been observed. (Diaz et al). According to the transmission deficit theory, the absence of redundancy in the phonological and orthographic nodes makes the phonological system particularly susceptible to age-related decline. (Burke and Shafto 2004), which may contribute to higher retrieval rates in PNDs. Our two variables, PND and frequency, can interact in picture naming (Diaz et al 2021). Overall, these findings show that PND may consistently affect language production over the life span. Our data suggests that PNDs do predict increased word retrieval, even more so than frequency words. Our results may suggest that with increasing age, older adults may have greater difficulties with overt production, and have higher levels of activation in language-relevant areas as well as domain-general executive and memory resources. (Diaz et al 2021), we hope to correlate this finding with data analysis in the future.

References

Acheson, D.J., Wells, J.B., MacDonald, M.C., 2008. New and updated tests of print expo- sure and reading abilities in college students. Behav. Res. Methods 40 (1), 278–289

Arbuckle, T. Y., M. Nohara-LeClair, and D. Pushkar. 2000. Effect of off-target verbosity on communication efficiency in a referential communication task. Psychology & Aging 15. 65–77.

Arbuckle, T., and D. Gold. 1993. Aging, inhibition, and verbosity. Journal of Gerontology 48. 225–32.

Braver, T.S., Barch, D.M., 2002. A theory of cognitive control, aging cognition, and neuromodulation. Neurosci. Biobehav. Rev. 26 (7), 809–817. doi: 10.1016/S0149-7634(02)00067-2.

Burke, D. M., & MacKay, D. G. (1997). Memory, language, and ageing. Philosophical Transactions of the Royal Society: Biological Sciences, 352, 1845–1856.

Burke, D. M., & Shafto, M. A. (2004). Aging and language production. Current Directions in Psychological Science, 13, 21–24.

Burke, D. M., and M. A. Shafto. “Language and Aging.” Edited by F.I.M. Craik and T. A. Salthouse. The Handbook of Aging and Cognition. New York: Psychology Press, 2008.

Burke, D. M., D. G. Mackay, J. S. Worthley, and E. Wade. “On the Tip of the Tongue: What Causes Word Finding Failures in Young and Older Adults?” Journal of Memory & Language 30 (1991): 542–79. https://doi.org/10.1016/0749-596X(91)90026-G.

Burke, D. M., MacKay, D. G., & James, L. E. (2000). Theoretical approaches to language and aging. In T. Perfect & E. Maylor (Eds.), Models of cognitive aging (pp. 204–237). Oxford: Oxford University Press.

Burke, D.M., Mackay, D.G., Worthley, J.S., Wade, E., 1991. On the tip of the tongue: What causes word finding failures in young and older adults? J. Memory Language 30, 542–579 .

Cabeza, R., Anderson, N. D., Houle, S., Mangels, J. A. & Nyberg, L. Age- related differences in neural activity during item and temporal- order memory retrieval: a positron emission tomography study. J. Cognitive Neurosci. 12, 1–10 (2000).

Cabeza, R. 2002. Hemispheric asymmetry reduction in older adults: the HAROLD model. Psychology & Aging 17. 85–100.

Cabeza, R., N. D. Anderson, J. K. Locantore, and A. R. McIntosh. "Aging Gracefully: Compensatory Brain Activity in High Performing Older Adults." Neuroimage 17, no. 3 (2002): 1394–1402. https://doi.org/10.1006/nimg.2002.1280.

Christensen, K.J., Moye, J., Armson, R.R., Kern, T.M. , 1992. Health screening and random recruitment for cognitive aging research. Psychol. Aging 7 (2), 204.

Conway, A.R., Kane, M.J., Bunting, M.F., Hambrick, D.Z., Wilhelm, O., Engle, R.W., 2005. Working memory span tasks: a methodological review and user's guide. Psych on. Bull. Rev. 12 (5), 769–786.

Diaz, M. T., M. A. Johnson, D. M. Burke, and D. J. Madden. 2014. Age-related Differences in the Neural Bases of Phonological and Semantic Processes. Journal of Cognitive Neuroscience 26. 2798–811

Diaz, M.T., Hogstrom, L.J., Zhuang, J., Voyvodic, J.T., Johnson, M.A., Camblin, C.C., 2014. Written distractor words influence brain activity during overt picture naming. Front. Human Neurosci. 8, 167. doi: 10.3389/fnhum.2014.00167.

Diaz, M.T., Johnson, M.A., Burke, D.M., Madden, D.J., 2014. Age-related differences in the neural bases of phonological and semantic processes. J. Cogn. Neurosci. 26 (12), 2798–2811. doi: 10.1162/jocn_a_00665.

Diaz, M.T., Johnson, M.A., Burke, D.M., Truong, T., Madden, D.J., 2018. Age-related differences in the influence of task-irrelevant information on the neural bases of phono- logical and semantic processes. Cognitive, Affective, Behav. Neurosci. 19 (4), 829844. https://doi.org/10.3758/s13415-018-00671-2.

Federmeier, K. D., and M. Kutas. 2005. Aging in context: age-related changes in context use during language comprehension. Psychophysiology 42. 133–41.

Gerlach, C., Aaside, C.T., Humphreys, G.W., Gade, A., Paulson, O.B., Law, I., 2002. Brain activity related to integrative processes in visual object recognition: bottom-up integration and the modulatory influence of stored knowledge. Neuropsychologia 40 (9), 1254–1267. doi: 10.1016/s0028-3932(01)00222-6, doi: https://doi.org/.

Gertel, V. H., Karimi, H., Dennis, N. A., Neely, K. A., & Diaz, M. T. (2020). Lexical frequency affects functional activation and accuracy in picture naming among older and younger adults Psychology & Aging, Advance online publication. doi: https://doi.org/10.1037/pag0000454

Geva, S., P. S. Jones, J. T. Crinion, C. J. Price, J. C. Baron, and E. A. Warburton. 2012. The effect of aging on the neural correlates of phonological word retrieval. JournalofCognitiveNeuroscience24. 2135–46.

Good, C. D., I. S. Johnsrude, J. Ashburner, R. N. A. Henson, K. J. Friston, and R. S. J. Frackowiak. 2001. A voxel-based morphometric study of ageing in 465 normal adult human brains. NeuroImage 14. 21–36.

Graves WW, Grabowski TJ, Mehta S, Gordon JK. A neural signature of phonological access: distinguishing the effects of word frequency from familiarity and length in overt picture naming. J Cogn Neurosci. 2007 Apr;19(4):617-31. doi: 10.1162/jocn.2007.19.4.617. PMID: 17381253.

Graves, William W., Thomas J. Grabowski, Sonya Mehta, and Jean K. Gordon. "A Neural Signature of Phonological Access: Distinguishing the Effects of Word Frequency from Familiarity and Length in Overt Picture Naming." Journal of Cognitive Neuroscience 19, no. 4 (April 2007): 617–31. https://doi.org/10.1162/jocn.2007.19.4.617.

Hamm, V. P., and L. Hasher. 1992. Age and the availability of interference. Psychology & Aging 7. 56–64.

Hasher, L., Zacks, R.T., 1988. Working memory, comprehension, and aging: a review and a new view. In: Bower, G.H. (Ed.). In: The Psychology of Learning and Motivation, 22. Academic Press, San Diego, CA, pp. 193–225.

Hasher, L., and Rose T.Z.1988. Working memory, comprehension, and aging: A review and a new view. The Psychology of Learning and Motivation, ed. by G. H. Bower, 193–225. San Diego, CA: Academic Press.

Healey, M. K., K. L. Campbell, and L. Hasher. 2008. Cognitive aging and increased distractibility: costs and potential benefits. Essence of Memory 169. 353–63.

Heim, S., Opitz, B., Müller, K., Friederici, A.D., 2003. Phonological processing during language production: fMRI evidence for a shared production-comprehension network. Cognitive Brain Res. 16 (2), 285–296. doi: 10.1016/s0926-6410(02)00284-7, doi:. Huettel, S.A., Song, A.W. , McCarthy, G. , 2014. Functional Magnetic Resonance Imaging, 3rd ed. Sinauer Associates.

James, L. E. &, Burke, D. M. (2000). Phonological priming effects on word retrieval and tip-of the-tongue experiences in young and older adults. Journal of Experimental Psychology: Learning, Memory and Cognition, 26, 1378–1391.

Kemper, S., A. Crow, and K.Kemtes. 2004. Eye-fixation patterns of high- and low-span young and older adults: down the garden path and back again. Psychology & Aging 19. 157–70.

Kemper, S., R. E. Herman, and C. H. T. Lian. 2003. The costs of doing two things at once for young and older adults: Talking while walking, finger tapping, and ignoring speech or noise. Psychology & Aging 18. 181–92.

Lustig, C., & Hasher, L. (2001). Implicit memory is not immune to interference. Psychological Bulletin, 127, 618–628.

Lustig, C., L. Hasher, and R. T. Zacks. 2007. Inhibitory deficit theory: recent developments in a "new view". The place of inhibition in cognition, ed. by D. S. Gorfein, and C. M. MacLeod. Washington, D.C.: American Psychological Association.

Lustig, C., L. Hasher, and S. T. Tonev. 2006. Distraction as a determinant of processing speed. Psychonomic Bulletin & Review 13. 619–25.

MacKay, D. G., & Burke, D. M. (1990). Cognition and aging: New learning and the use of old connections. In T. M. Hess (Ed.), Aging and cognition: Knowledge organization and utilization (pp. 213–263). Amsterdam: North Holland.

MacKay, D. G., and D. M. Burke. 1990. Cognition and aging: a theory of new learning and the use of old connections. Aging and cognition: knowledge organization and utilization, ed. by T. M. Hess, 213–63. Amsterdam: Elsevier.

MacKay, D. G., and L. E. James. 2004. Sequencing, speech production, and selective effects of aging on phonological and morphological speech errors. Psychology & Aging 19. 93–107.

Madden, D.J., Pierce, T.W., Allen, P.A., 1993. Age-related slowing and the time course of semantic priming in visual word identification. Psychol. Aging 8 (4), 490–507. doi: 10.1037/0882-7974.8.4.490.

Sommers, M. S. (1996). The structural organization of the mental lexicon and its contribution to age-related declines in spoken-word recognition. Psychology and Aging, 11, 333–341.

Thornton, R., & Light, L. L. (2006). Language comprehension and production in normal aging. In J. E. Birren and K. Warner Schaie (Eds.), Handbook of the psychology of aging (pp. 262–287). Burlington, MA: Elsevier.

Vitevitch, M. S., & Sommers, M. S. (2003). The facilitative influence of phonological similarity and neighborhood frequency in speech production in younger and older adults. Memory & Cognition, 31, 491–504.

Vitevitch, M.S., 1997. The neighborhood characteristics of malapropisms. Lang. Speech 40 (Pt 3), 211–228. doi: 10.1177/002383099704000301.

Vitevitch, M.S., 2002. The influence of phonological similarity neighborhoods on speech production. J. Exper. Psychol. 28 (4), 735–747. doi: 10.1037/0278-7393.28.4.735.

Wilson, S. J., A. L. Isenberg, and G. Hickok. "Neural Correlates of Word Production Stages Delineated by Parametric Modulation of Psycholinguistic Variables." Human Brain Mapping 30 (2009): 3596–3608. http://dx.doi.org/10.1002/hbm.20782.

Wlotko, E. W., C. L. Lee, and K. D. Federmeier. 2010. Language of the aging brain: event-related potential studies of comprehension in older adults. Language & Linguistics Compass 4. 623–38.